THE
ECONOMIC GEOLOGY
OF
ORISSA

(With a Mineral Map of Orissa)

BY

OFFICERS OF THE

GEOLOGICAL SURVEY OF INDIA

REVISED AND BROUGHT UP TO DATE

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SUPERINTENDENT

ORISSA GOVERNMENT PRESS

CUTTACK

1949

LIST OF AGENTS

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THE

ECONOMIC GEOLOGY OF ORISSA

PART I

ECONOMIC ASPECTS OF GEOLOGY IN ORISSA

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PART II

THE RECORDED MINERAL OCCURRENCES OF ORISSA

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THE

ECONOMIC GEOLOGY OF ORISSA

Part I

ECONOMIC ASPECTS OF GEOLOGY IN ORISSA

(By J. A. DUNN)

CHAPTER I

INTRODUCTION

The territory covered by the province of Orissa is, geologically, one of the least known regions of India. Apart from occasional traverses made by geologists during the last 80 years, and a little detailed mapping in selected areas, no systematic work has been done and our knowledge of the greater part of the province is only broad in outline. Following upon the separation of Orissa from Bihar, arrangements were made by the Geological Survey to commence a systematic survey of the new Province, and three officers were appointed in 1939 for this purpose. In order to obtain the maximum amount of information immediately, a preliminary survey was made of all reported mineral occurrences. It was hoped that examination of these would give a clear idea of their value, and would provide some suggestion not only of what minerals are likely to be found in the future, but also of the areas in which geological mapping should be commenced. It must be emphasised, then, that this account is entirely preliminary in character, based only on the known deposits which have been visited by officers of the Geological Survey. In the future, it is hoped that detailed geological mapping, which was commenced a few years back and will now be continued over a period of years, will bring to light other occurrences of value, but such work is necessarily slow and immediate results cannot be expected.

The object of this account is to give a present-day picture of the known geological resources of the province and to stimulate interest in these matters, so that the fullest use may be made of the advice which is now available. Views on the various mineral resources have been stated explicitly wherever possible, whether they be favourable or otherwise. In addition, the direction in which further development should be encouraged has been indicated. The prospector is informed of those minerals for which he may usefully search within the province; it is hoped that he will find herein hints to guide him in his search, and he is definitely informed of those minerals for which no market may be expected. The research worker, it is hoped, will find information which will provide him with lines of enquiry to pursue in the furtherance of the mineral development of the province. Much of the information provided is of a negative character but will, perhaps, save future needless expenditure.

Some aspects of the relation of the State to the mineral industry are reviewed. The mineral owners, whether they be Zemindars or

Government, may find herein information which will help them to a balanced appreciation of the real value of the mineral deposits which they may lease out. Not uncommonly, the monetary value of a mineral deposit has been grossly exaggerated and its proper development accordingly hindered. At times the intrinsic value of mineral occurrences in some parts of India has been under-appreciated and Government, in particular, has not obtained that revenue to which it should have been entitled.

Views are recorded on such matters as rents, royalties and taxation affecting mineral development, and on geological questions affecting engineering, forestry and agriculture in Orissa, so that district officers and Government officials of various department may have available information which may prove a helpful guide in their work. To such officials, however, the fact must be stressed that geological problems must be treated individually, and that the information provided should not be substituted for the services of a geologist. On the contrary it is hoped that this account will lead to an increasing use being made, on the part of the Provincial Government, of the experience and advice of the geologist in *all* questions related to the mineral industry.

A further object has been to provide information which will assist Government to a precise understanding of the probable capabilities of the province for mineral development. The views expressed on the form which Government encouragement should take may, perhaps, be regarded as relevant.

By a judicious use of the Index, readers should find it possible to obtain information on each district, locality and mineral.

The account has been divided in two parts, Part I dealing in general terms with the economic aspects of geology in Orissa, Part II dealing only with the mineral occurrences. Chapters on Physiography and Geology in Part I may, at first, be thought a little too theoretical for a work of this nature, but some knowledge of these subjects is essential if the varied applications of geology to engineering, agriculture, forestry and industry generally are to be appreciated.

The descriptions of the deposits in Part II are written by the officers who were responsible for each district, so that this report is a full compilation of the recent work undertaken by the Geological Survey.

CHAPTER II

PHYSIOGRAPHY

The study of physiography in India has been almost completely neglected. Even in the better known province of Bihar anything approaching a detailed study has been made only recently, whilst attempts at interpretation of the physiography of Orissa in terms of crustal movements have been completely lacking. Our knowledge of the terrain is too scanty for any detailed description to be made of

the processes by which the physical features have come into being, but it is advisable to sketch in broad outline the basic movements underlying physiographic development in Orissa.

We may picture the Indian Peninsula as a triangular slab with its eastern and western edges curled up—these edges forming the Eastern and Western Ghats respectively. In earlier geological times the zone now occupied by the Eastern Ghats in Orissa was at base level, comparable with the present-day lower levels of the central part of the Peninsula, the streams all draining eastward. Even at that time the main streams, the Brahmani, the Mahanadi and the Godavari were in existence. The general slope of the surface was, then, eastwards; this surface was flat to gently undulating, but with residual hills rising here and there a further one to two thousand feet. Some time subsequent to the deposition of the Gondwana beds south-west of Cuttack and in Angul, the eastern zone commenced to rise along a belt extending from the Chota Nagpur plateau in Bihar, through Keonjhar and the Eastern States, across the Mahanadi, south through Ganjam and Koraput and into Madras. Downward erosion along the old drainage lines, however, kept pace with this uplift and the main streams maintained more or less their old courses. It is also probable that stream alignments were partly influenced by trough-faulting in the direction of the main river valleys, as it will be noted that the faulted boundaries of the Talchir-Rampur Gondwana basins follow the trend of the main N. W.-S. E. valleys. Problems such as this will presumably be studied during future work.

Uplift did not take place as a single stage. The first uplift was of the order of about 1,000 feet, giving rise to a plateau, the edges of which soon became deeply eroded. The undulating uplands of this plateau became covered with an extensive capping of laterite. The Koraput plateau and the high hills of the Eastern Ghats are the representatives of this early lateritised surface.

After prolonged erosion of this old plateau, during which its western part was reduced to a peneplain, uplift was renewed. The older surface was carried to a level of 3,000 feet, and the newer peneplain to 2,000 feet. Subsequent erosion has removed much of this second peneplain, but part of it is preserved in the 2,000-foot plateau of Jeypore, and the Khariar plateau of Sambalpur. It is not clear whether this second period of uplift was continuous, or whether it took place in stages; from a knowledge of the contemporaneous movements in Bihar it may be suspected that the movement took place in stages.

The eastern border of this belt of uplift is probably not a fault line, but rather a narrow zone of abrupt warping which can be followed more or less continuously from the eastern edge of the Chota Nagpur plateau in Bihar, south through Keonjhar and, crossing the Mahanadi continues parallel with the coast but inland a few miles, into Madras. This line or narrow zone of upwarp has been maintained by the successive stages of uplift. East of this line of upwarp is the coastal zone proper which slopes gradually to the Bay of Bengal. Naturally the uplift has caused rejuvenation of stream activity, and the streams have cut deeply into the eastern scarp so that its delineation is now extremely irregular.

At the northern end of this coastal zone, along the western edge of Bengal and the south-eastern edge of Bihar, there has been more recent uplift varying in amount between 250 feet and 700 feet. At first it was suspected that evidence of a similar uplift would be found all along the coast, but in the Mahanadi delta and the coastal deposits to the south no clear evidence has been found as yet of what the general direction of movement may be. Reports of laterite at the bottom of the boreholes in the Mahanadi, at Cuttack, at a level nearly 100 feet below the adjacent surface laterite, may indicate subsidence. Around Chilka lake, however, certain deposits of shells of estuarine habit occur at 20-30 feet above the present high-water level of the lake, and indicate recent uplift. Oscillations in movement within a general period of uplift or subsidence have always to be taken into account. This question of the direction of movement in the coastal strip must receive close attention in the future as it will assist in any study of river flooding and irrigation and is of importance in anticipating tendencies for soil erosion.

The seaward edge of the coastal strip consists not only of river and littoral deposits but also of wind-blown sands. Accumulations of the latter give rise, in places, to ridges parallel with the coast. Chilka lake has been formed in part by the growth of sandpits and in part by the southern extension of the Mahanadi delta which has almost isolated this sheet of water from the Bay of Bengal.

On the western side of the Eastern Ghats the line of warping is neither so sharply nor so continuously defined. The sequence of events in Sambalpur district, extending into the Chhattisgarh basin, is not yet known, and to the south the edge of the Ghats extends into Raipur and Bastar. The Jeypore plateau is being subjected to rapid erosion by the headwaters of the various streams draining the low-lying tracts of Malkangiri.

CHAPTER III

GEOLOGY

To the geologist, mineral deposits are known to occur not entirely haphazardly. There is a connection between the geology of a region and the types of minerals which may be found in different parts of that region. With a detailed knowledge of the geology, although it may not be possible to assert that certain minerals must occur in particular areas, it is possible to say that certain minerals cannot possibly occur there. Frequently, one may even be in a position to advise that the geology is favourable to the occurrence of certain minerals in definite areas. A knowledge of the geology does, accordingly, narrow the area of search for particular minerals very materially.

Unfortunately, however, we have no detailed knowledge of the geology of Orissa, but are aware only in broad outline of the general distribution of the principal rock groups. Our advice on mineral distribution must, for the present, then, remain cautiously limited.

So far as we know at present the following are the main formations represented in Orissa, arranged in order of increasing antiquity:—

Alluvium ; blown sand

Laterite

? Tertiary

Post-Gondwana trap dykes

Gondwana	Upper	Athgarh stage
	Lower	Hingir or Kamthi stage Barakar stage Talchir stage

Cuddapah

Newer dolerite

Archean	Igneous rocks	Granite, pegmatite, charnockite: epidiorite, hornblende-schist: granitoid-gneiss, garnetiferous-gneiss, biotite-gneiss.
	Sedimentary rocks	Mica-schists, quartzites, banded hematite-quartzite, Bengpal series, khondalite.

Within the Archean sediments we are uncertain, as yet, of the relative ages of the various representatives.

By far the greater portion of the province is occupied by the Archean rocks, which form a basement to all the younger groups such as the Cuddapah, the Gondwanas, and the still more recent alluvium and laterite.

Some peculiarities are noticeable in the general strike of the structural lines in the Archeans of Orissa. In the Eastern Ghats and territory on either side the strike is N.N.E.-S.S.W. to N.E.-S.W. with some local variations trending north-south. The N.N.E. strike of the Eastern Ghats swings round to a general E.S.E. strike in Athmalik and Angul. The E.S.E.-W.N.W. strike prevails over the rest of Orissa but it commonly varies between N.W.-S.E. and east-west. Around Sambalpur town the strike is variable, in places becoming E.N.E.-W.S.W. The disposition of the later formations has been determined to a great extent by the trend of the Archean rocks, the parallelism between the strike of the Archeans and the trend of the Gondwana outliers being particularly noteworthy.

The Archeans of Orissa may be divided into two main rock groups: (1) sedimentary rocks and their metamorphic variants, with which are associated basic igneous rocks, and (2) widespread intrusions of granite and charnockite. On the basis of the presence or absence of garnets in the rocks Sir L. L. Fermor some 20 years ago drew a dividing line across the region: the garnetiferous varieties to the south were called the Eastern Ghats facies and the non-garnetiferous rocks to the north were called the Chota Nagpur facies. As it happens, garnet-bearing

rocks occur within the area of his Chota Nagpur facies and, for the present, it is considered advisable to abandon Fermor's classification.

The sedimentary Archean rocks of the Eastern Ghats are highly metamorphosed. The chief rock-type consists of quartz, garnet and sillimanite, with some felspar and graphite and possibly manganese and iron minerals, and is known as khondalite. In a few localities, calc-gneisses, quartz veins, garnetiferous quartzite, and crystalline limestone are associated with typical khondalite. Khondalitic rocks form part of the Koraput plateau, which passes southwards into Vizagapatam and northwards into Kalahandi State. In Ganjam and south-west Puri districts, the khondalites occur as beds between dyke-like masses of quartzite, or in the form of hills and ridges supported by quartzite and granite-gneiss. In general, the khondalites of the Eastern Ghats occur as broad bands in the gneisses and charnockites and in places enclose intrusions of a massive granite.

Metamorphosed Archean sediments of a different type, which have not suffered such intense metamorphism as the khondalites, occupy large areas on the western and south-western part of the Jeypore plateau and extend into the lower tracts of Malkangiri. These rocks, known as the Bengpal series, extend westwards into Bastar State where they are better developed, and were first studied and named by Dr. H. Crookshank. Included within the Bengpals of Koraput district are andalusite-bearing grits and schists, chlorite and biotiteschists, and coarse crystalline quartzite, and associated with them are hematite-quartzite, banded magnetite and grunerite-quartzite, and calc-granulite.

In Sambalpur district the Archean sediments are represented by calc-granulite, quartz-mica-schist, mica-schist, quartzite, phyllite and calc-silicate rocks. Quartz-schists are also present in Balasore district. It is possible that these may be related to the Iron-ore series of Bihar.

The above Archean sediments are associated with basic lavas and minor intrusions, which are present also in the gneisses described next. The basic rocks have been subjected to varying degrees of metamorphism and in all probability belong to more than one period. They consist of epidiorites, amphibolites, hornblende-, diopside-, chlorite- and talc-schists. The greenstone intrusions in the Bengpals of Jeypore, in the Tulsi and Lekki hills, assume enormous proportions for rocks of this type.

By far the most widespread rocks of Orissa are the gneisses, which form a complex group of igneous and metamorphic rocks, so much altered by regional metamorphism and different cycles of igneous activity that the nature of the parent rocks cannot always be determined Some of them may represent the crystalline products of true melts while others appear to be hybrids, or remnants of older rocks which have absorbed granitic liquid or have been altered by gaseous and liquid emanations. The gneisses may be divided into porphyritic granite-gneiss, garnetiferous granitoid gneiss, fine-grained biotite-gneiss, and charnockites. Of the above the porphyritic granite-gneiss is the most prevalent type; it occupies large areas on Jeypore plateau and in Sambalpur district and is a biotite-granite, although in places hornblende is present in addition. The gneiss is well-foliated, the direction of foliation generally conforming to the strike of the sedimentary rocks such as the khondalites or mica-schists. With the absence of foliation

the gneiss passes into a massive granite, which may represent merely a non-foliated variety of the gneiss or may be a later intrusion. The granite varies widely from fine to coarse-grained porphyritic types; in the latter, phenocrysts of felspar may be as much as a foot long and several inches across. Veins of pegmatite and quartz are commonly associated.

Garnetiferous-gneisses occupy the Eastern Ghats. They are mineralogically similar to biotite-granite but characterised by an abundance of red garnet. They vary from coarse-grained banded gneisses and typical injection gneisses to entirely massive granites, and carry bands and patches of basic hypersthene-granulite and other dark-coloured rocks. Basic charnockites occur in the form of minor patches or bands. Associated with the granite-gneiss near Koraput are some very interesting nepheline-syenites. These are of two types, the first light in colour with streaks and patches of biotite and hornblende, the second composed of large porphyritic masses of nepheline in a mylonitic martrix.

Immediately on the western side of the charnockite massif of the Eastern Ghats in Malkangiri *tahsil* occurs a very fine-grained biotite-gneiss quite different from the coarsely crystalline granite-gneisses described hitherto. It consists of fine angular grains of quartz and felspar with a variable but small quantity of green biotite. This gneiss was formerly regarded as sedimentary in origin, but Dr. Crookshank thinks it is a granulated variety of a slightly porphyritic granite-gneiss which occurs further west. Garnet is rather rare in this biotite-gneiss, which is associated with numerous bands of hornblende-schist of uncertain origin. Large masses of white crystalline quartzite occur in many places among the hornblende-schists and biotite-gneisses.

The charnockites are regarded as a series of igneous rocks varying in composition from ultrabasic to acid and characterised by the presence of the mineral hypersthene. In Orissa they are practically confined to the Eastern Ghats, and have been intruded into the khondalites giving rise to some very interesting contact phenomena in certain localities. The most striking of these is the development of the rare mineral sapphirine and green spinel and, locally, cordierite. Massive charnockites grade to hypersthene-gneisses, which also vary in composition from basic to acid, and these in turn are found to grade to biotite-gneisses. It is difficult, in places, to decide whether to classify some specimens as charnockite or as biotite-gneiss.

Associated with the hypersthene-gneisses of Malkangiri some gneissic soda-granites are believed to have originated by the invasion of the pre-existing rocks by alkaline solutions. The soda granites are perhaps younger than the greater mass of granites. It is not known what relation they bear to the massive granites and pegmatites so common in the gneisses of Orissa.

It may be pointed out that the trend of the schistose inclusions in the gneisses, the strike of basic rocks and khondalites and the trend of the Cuddapahs and Gondwanas, all conform to the foliation of the gneisses in their neighbourhood.

Dolerites, which are commonly almost unaltered, occur locally as dykes and sills in the gneisses to the west of the Eastern Ghats and also

in the charnockites of the main range, where they carry garnet. In hand specimens they are black rocks barely distinguishable from greenstones or epidiorites and have escaped the earlier metamorphism which converted the older basic dykes into epidiorites. The age of this newer dolerite is clearly younger than that of the charnockites, as dykes of it cut the charnockites in several places. None of these newer dolerite dykes have yet been found to intrude into the Cuddapahs and in all probability the newer dolerites are older than the Cuddapah system.

The next higher formation in the geological scale is at present correlated as Cuddapah; in Sambalpur two groups have been distinguished in the past, one correlated as Cuddapah and the other as Vindhyan, but we know little about them and, for the present, they will all be grouped as Cuddapah. Exposures of this group are known in several places in the Koraput and Sambalpur districts, where they rest unconformably on the schists and gneisses of Archean age. In Koraput district the Cuddapahs crop out along the Bastar-Jeypore border from latitude 18°22′ to latitude 18°32′ and again from latitude 18°48′ to latitude 19°21′; another outlier is present along the Jeypore-Kalahandi border to the north of Nowrangpur. The rocks are normally horizontally bedded, but marginally they are frequently folded and faulted. The main part of this series in Koraput district is formed of purple shale and slate, with intercalations of limestones, in places overlying a variable thickness of coarse white quartzite. In Sambalpur district such sedimentary beds extend along the district boundary north-west and south-west from about 13 miles west of Sambalpur town. The lowest beds consist of sandstones, overlain in many places by clays and clayey shale, succeeded by limestone, which is the most abundant representative at the surface. Near Padampur there are four distinct zones of limestone; in the Barapahar hills, along the north-west edge of the district, the Cuddapahs consist of shales, sandstones and quartzites, all highly disturbed. These latter do suggest the occurrence in Sambalpur of two separate systems between the Archeans and the Gondwanas.

The Gondwanas are separated by a great hiatus from the older rocks of the Indian Peninsula. The lowest beds of the formation are composed of grooved, striated and scratched boulders of pebbles in grits and fine clays now forming shales, the whole comprising a group of glacial deposits. The higher coal-bearing beds are fluviatile and lacustrine sediments, consisting of sandstones, shales, fireclays, and coal-seams. The Gondwanas of Orissa are restricted to certain well-defined areas in Sambalpur, Cuttack, Puri and Ganjam districts. The parallelism between the trend of the Gondwanas in Sambalpur and Angul and of the adjacent Archeans has already been noted. North of Sambalpur, the abnormal strike of the Archeans is reflected in the strike of the Rampur coalfield, lying partly in Orissa and partly in the Central Provinces. Further south-east the Gondwana rocks of the Talchir coalfield are aligned E.S.E.-W.N.W., where the strike of the Archeans also runs in the same direction.

The Gondwanas of Sambalpur district belong to the lower division. The lowest series is represented by the Talchir boulder beds which rest directly on the gneisses and are succeeded by shales and sandstones. The next higher series, the Barakars, carries coal and coal-shale interbedded with sandstones, and the uppermost series of sandstones is correlated as Kamthi. From the coalfield, the lowest beds, the Talchirs, are prolong-

ed south-east for about 36 miles to the Brahmani river in Rairakhol. This prolongation is possibly the remnant of an ancient valley, narrower and more defined during the Talchir period than the present Brahmani valley.

A fairly large exposure of Upper Gondwana rocks occurs in the Mahanadi basin, just west of the delta. The rocks on the northern side of the river, between Cuttack and Athgarh, are known as Athgarh sandstones and consist of grits, coarse sandstones, conglomerates and white or pinkish clay beds. The Athgarh beds are thought to be equivalent to the Rajmahal beds of Bihar. The same rocks continue south of the Mahanadi into north Puri district, where extensive exposures are present.

Outliers of Gondwana rocks have recently been found in the Khondmals, in Ganjam district, where they rest unconformably on gneisses. They consist of conglomerates, grey, black and white shales with sandstones and ferruginous sandstones on the top. They are correlated for the present with the Gondwana formations of the Mahanadi basin, but their exact age has not yet been determined.

Dolerite dykes which cut the Gondwana rocks of Orissa are not so prolific as in Bihar. At one place, on the south bank of the Mahanadi west of Cuttack, a basalt (dolerite) dyke pierces the Athgarh sandstones. In several places in Ganjam district the Gondwanas are cut by dykes of fresh dioritic rocks.

A large part of the province, especially near the coast, is covered with irregular deposits of laterite at various altitudes. The laterite cappings on the Eastern Ghats plateaux in Ganjam and Koraput districts are over 3,000 feet high. High-level laterite are also known at heights of 3,000 to 4,000 feet, capping the khondalites of Gandamardhan hill on the Sambalpur-Patna border, and on Kopilas hill near Cuttack about 2,050 feet above sea-level. It is also found on the 2,000-foot Jeypore plateau near Kotpad. On the other hand, some of the laterites in juxtaposition with the deltaic alluvium in Puri and Cuttack districts are not many feet above sea-level. Low-level laterites occur as a belt at intervals along the western edge of the alluvial tracts in western Balasore, Cuttack and Puri districts.

It is thought that commencement of formation of the high-level laterite dates back, perhaps, to Eocene, but the low-level laterite is, on the whole, Pleistocene to present day in age. The old view that the low-level laterite has been derived by erosion and re-deposition of high-level laterite must be abandoned as it does not fit the facts. Both high- and low-level laterites are a special form of surface alteration of the underlying rocks, which can take place at any altitude and is determined by climate and drainage.

It has already been mentioned that the coastal tracts of Balasore, Cuttack and Puri districts are constituted by the deltaic alluvium of the Mahanadi, the Brahmani and the other rivers of Orissa, with also littoral deposits. Like the Gangetic alluvium, these coastal deposits in Orissa can be divided into (*a*) older sediments occupying the higher ground and containing gravels with often much surface ***kankar***, and (*b*) recent alluvium, of silt and clays and fine sands. It is not impro-

bable that some of the older sediments may prove to be Tertiary in age. In addition, there are tracts of *blown sands* along the coast resulting in ridges of sand hills. Wise planting of casuarina many years ago has restricted the movement of this wind-blown sand. Evidence of the recent retreat of the sea consequent on uplift of the coast is suggested around Chilka lake, where a considerable deposit of estuarine shells stands at a height of 20 to 30 feet above the present high-level of the lake. None of the species have been observed living in Chilka lake although one of them is abundant in the estuary connecting the lake with the sea.

CHAPTER IV

GEOLOGY IN ENGINEERING, FORESTRY AND AGRICULTURE

UNDERGROUND WATER-SUPPLY

The question often arises whether water can be obtained by sinking tube wells in certain regions. It may be said at once that tube wells are effective only in alluvial country and that over the greater part of Orissa boring for water is inadvisable.

The Mahanadi delta and the part of the coastal tract covered by alluvium is suitable for the sinking of tube wells wherever the alluvium is sufficiently deep. Information on the sequence and distribution of the sands and silts which constitute this alluvium and the type of water they contain, is lacking. A close record should be kept so that eventually clear advice can be given on the depths and distribution of brackish and sweet water within the alluvium.

Away from the coastal alluvium, only normal wide-diameter wells are recommended. There may be a few isolated instances in which local deep alluvium, or a very deep capping of porous decomposed material over fresh granite, would permit the successful use of tube wells, but their location would be fortuitous. In the Gondwanas, wide-diameter wells may be sunk not only in the surface soil cap but also in the sedimentary rocks with fair chance of success. On the granitic rocks and gneisses, once the well has been sunk through the surface cap of soil and decomposed rock, there is normally little chance of obtaining water in the solid rock below, unless this happens to be closely fissured. In schists the chances of success of wells vary according to the type of rock penetrated.

The water table in the granitic rocks and gneisses follows the surface topography, but surface valleys and ridges tend to be flattened out in the underlying water table. In other words the water table is met with at a greater depth below surface on ridges than in valleys—it may even reach the surface in the latter. The depth to which the surface soil and decomposed rock extends is extremely variable. In seeking well-sites, thickness of soil cap and direction of drainage are a guide to some extent. Where such resistant features as a basic dyke, or a quartz vein, or possibly even a fault, may hold up the flow of sub-soil water, there a good well-site may be sometimes located. Such a site, along

the bank of a stream where there is a good depth of sand, is frequently ideal, and may yield an excellent quantity of water. Where, however, very large quantities of water are required then it is advisable to instal an infiltration pipe in the sands of the river bed.

The above points may serve merely as an indication of the difficulties in approaching questions of underground water-supply. The engineer is well advised, however, to obtain the opinions of a geologist who will consider each case on its own merits.

Reservoirs and dam sites

The storage of bodies of water for irrigation and other purposes is one of the oldest engineering features of India. These storages vary from small simple village tanks (used frequently for irrigation as well as for drinking and washing purposes) to large reservoirs with masonry or concrete dams. In the future, as the population increasingly segregates into large town centres, it will become necessary to find storage for water-supply to these towns. In the Eastern Ghats, sites will also be found for the impounding of water at high levels in conjunction with hydro-electric schemes, which are likely to form the principal power supply of the future in Orissa.

This is not the place to enumerate the water storage sites within the province; too many factors of a technical character are involved which require the close co-operation of engineer and geologist. Rivers cutting across residual ridges may provide sites for reservoirs. Rivers descending from plateau scarps provide hydro-electric possibilities.

In the examination of a reservoir project, apart from the water-tightness of the reservoir basin itself the main concern of the geologist is the dam foundation and the materials to be used for construction. Frequently the reservoir basin may be suitable but the site on which the dam is to be founded may possess weaknesses. Such weaknesses may even mean that the project must be abandoned, but sometimes it may be possible to design the structure to avoid the weakness, or it may be possible to choose an alternative site for the dam. Occasionally it may be necessary to carry the foundations down to such a depth that the whole project becomes economically impracticable.

Judging from the broad knowledge which we have of the geology of Orissa there should be few difficulties in likely dam foundations, and almost throughout the province suitable materials for construction should be found close at hand.

Railway alignments

There have been instances, in India, of railway alignments being chosen along which water-supply difficulties were encountered after construction. Alternative alignments may have been possible along which water-supply would be ample. In the preliminary survey work of railway alignments the geological aspect should always be kept in mind and advice sought on water supply, bridge foundations, safety of cuttings and tunnels and the supply of building materials. No detailed advice can be given here, but it may be insisted that engineers should make use of the geological knowledge available in the province.

Road alignments

The choice of alignment of roads is often partly determined by the best sites available for bridges at river crossings. No detailed advice can be given, but here again geological opinion should be sought. In steep hill country geological advice may lead to the avoidance of sections susceptible to landslips. The availability of suitable road metals close to the road is also important.

Soils

From the point of view of origin, soils are of two types: (*a*) those formed of material which has been transported from some distance and (*b*) residual soils or those formed by the alteration of the immediately underlying rocks. The former occur along the bottom of river valleys, the latter type are found on elevated tracts, hills and plateaux.

The valley sediments will, of course, consist of a mixture of all the material brought down by the streams from the rocks of the watershed, although there may be some tendency for sorting of these sediments according to grain size and gravity. With the admixture of sandy material from sandstones, quartzites and granites with clayey material from shales, phyllites and basic igneous rocks, the tendency along the valley bottoms is to the accumulation of light sandy soils. In such cases, however, where the streams traverse only siliceous rocks or rocks which provide a clay soil, then the sediments can only be sands or clays respectively. The well known black soils consist partly of a clay mineral known montmorillonite, notable for its remarkable swelling properties on wetting; these soils are usually rather limey.

Over the greater part of Orissa, the streams are draining granitic and gneissic rocks, so that the sediments are mainly sandy, but clay constituents increase downstream in consequence of sorting and the sediments are usually of the nature of light loams over the Mahanadi delta.

Away from the valleys the soil forms merely a cap of varying thickness, derived by alteration of the rocks below so that their nature will depend on those rocks. The granite, which is so widespread, gives rise to a rather coarse sandy soil with just sufficient clay to hold it together. On the high plateau country this granite soil generally contains a certain amount of iron hydroxide, which causes the soil in the dry season to set almost as hard as cement at the immediate surface. Such soils are not particularly fertile as a rule. They are frequently known as "red soils" and represent a very old soil surface.

Over the mica-schists, which occur as patches of variable extent in the granite area of Sambalpur, the soil cap is much more argillaceous. Khondalites of the Eastern Ghats are usually deeply weathered and give rise to a soil varying from sand to a heavy loam according to the amount of free quartz present in the original khondalite. Acid charnockites will give rise to light loams, but the basic rocks will provide heavy clay soils on decomposition.

Quartzites and quartz-schists constitute quite extensive outcrops in parts of Sambalpur, forming hill-country. There is little or no soil cap

on these hills, and along their flanks the soil shed from them may be very sandy for some distance.

Over the Gondwanas of Sambalpur, Cuttack and Puri districts, the soils are usually rather heavy loams. The rocks comprise alternating shales and sandstones, but the latter normally contain a considerable proportion of felspathic grains which weather to kaolin. On the whole the flatter, low-lying coalfields country is more widely covered with re-distributed surface capping than are the highlands.

The formation of laterite is described in Chapter IX but, briefly, it may be said that where the drainage is suitable at any altitude, in a climate of alternating prolonged wet and dry seasons, the tendency i to the chemical accumulation of alumina and ferric hydroxide at the surface and the removal of silica in solution. Any rock, provided that it contains some alumina and iron, can give rise ultimately to a capping of laterite, but this capping will form more readily over rocks or sediments high in alumina and iron, such as over traps and shales.

Lateritic caps are commonly only a few inches thick, although they may vary up to many feet. In consequence of their dense fine-grained and colloidal nature, with high iron-content, they are useless for agricultural purposes and permit only a very sparse and poorly developed jungle growth.

In Orissa, laterites have formed not only on the old peneplain surfaces of the plateau country, but also along the edge of the coastal alluvium. Here in Orissa, so far as has been observed at present, this low-level laterite caps not only the Archean rocks, but also the Gondwana sandstones, although it is rarely more than a few feet thick. In Bihar and Bengal the laterite is known also to cap late Tertiary grits and gravels and it is not at all improbable that in Orissa it will be found to cap similar sediments which have been called "older alluvium."

The above broad outline of soil distribution merely serves to indicate the importance to both forestry and agriculture of a knowledge of the rocks in Orissa. It is based only on the relative silica-clay composition of the soils, but other constituents require consideration and of these lime is one of the more important, for it is found as *kankar* scattered on the soils over much of the province. Even when the underlying rocks or sub-soils contain the minimum amount of calcium, that amount becomes concentrated at the surface under the climatic conditions of this area. Other important soil constituents include potash, phosphates, manganese, etc., all of which are contributed by the underlying rocks, whilst organic material, such as carbon and nitrates and other salts derived from organic acids, have been made possible by vegetable and animal life. The distribution of these in various zones of the surface soil provides scope for an immense study. In agriculture the composition of soils is of importance not only from the point of view of crops, but also of animal life, for deficiency or excess of certain constituents may give rise to diseases.

A thorough soil survey of Orissa will eventually be a necessity. That survey must be based on the geology of the province, for, apart from a few of the organic acids and carbon, the soil derives the whole of its constituents from the rocks.

Soil erosion

In Chapter II the sequence of uplifts which has given rise to the plateaux of the Eastern Ghats were outlined. It will have been gathered that one effect of these uplifts has been the rejuvenation of stream activity and this activity is particularly prevalent along the edges of the plateaux, where the rocks and surface soils are being rapidly eroded.

Nature's demands—the erosion of the surface in an area of steepened gradient—cannot be denied, but they can be slowed down to some extent. The most rapid erosion in such an area is in the early stages, when the headwaters of the streams are beginning to remove the old soil cap. Once this cap is removed the eroding action of the streams on the underlying rocks is much slower.

Along the edges of the plateaux, such as to the south of Malkangiri, in Koraput, the soil cap over a wide area may become intersected by innumerable gullies, thus forming "bad lands". A very considerable amount of fertile land may, in this way, be destroyed. Once this type of erosion has commenced it can be slowed down by encouraging suitable vegetation to grow, both trees and grasses. But even this will reduce lateral erosion for only a very short time unless vertical erosion along the main drainage channels can be reduced by local checking of the streams to flatter gradients. This checking can be accomplished by means of a system of weirs along each stream. In many places the stream gradient is checked by natural barriers before lateral erosion has completely removed the soil cap; in such cases the lowered soil surface may be as fertile as the soil removed and can be planted with vegetation to prevent further erosion.

In the highly dissected regions of the Eastern Ghats the problem is entirely different; it is not a question of the prevention of destruction of flat agricultural lands but of erosion of soil from steeply inclined jungle hill-slopes. Here erosion commences from radial drainage lines which cut straight down the hill side, exposing the underlying rocks and then spreading laterally. The object here must be to prevent the formation of these radial gullies or, if formed, to break them up. Prevention is best done by contour trenching, which leads the drainage waters by gentle gradients to streams along which erosion can be controlled. In this way rapid local erosion can be quickly checked, and is converted to a gradual and more natural lowering of the soil surface of the whole hillside, permitting the concomitant formation of soil from the underlying rocks. Once erosion gullies have been formed their further development can be checked only by breaking up the gradient with a series of weirs and barriers and by re-planting.

In hill country soil erosion is aggravated by over-grazing and deforestation which remove the protective cover from the surface. In flat country, however, over-grazing and opening up of the soil by agriculture may be the sole determining factors in erosion of some areas, and, even in the absence of heavy rainfall and stream activity, may permit the complete removal of the surface soil by wind erosion.

So far as the writer is aware soil erosion in Orissa does not appear to have become such a serious problem as in some parts of India, where it has raised questions of grave importance not only to the agriculturist

and forester, but also to the engineer who has to minimise siltation of reservoirs, river channels and canals. There is apparently some confusion of thought and lack of appreciation of what is, in some cases inexorable, in others preventable, or in others unimportant. In some cases afforestation will provide a cure, in others engineering means must be used as prevention. A prolonged and careful study of the problem is essential but, apart from areas subject to wind erosion, it must be accompanied by a thorough appreciation of the forces of nature which are ultimately responsible for most erosion-crustal uplift.

CHAPTER V

LOCALISATION OF MINERALS, AND PROSPECTING

Geological distribution

Our knowledge of the geology of Orissa is, as yet, small, but it may be noted that most minerals occur more particularly with certain rock types. In the following list the mineral occurrences are grouped according to the geological formations with which they are so far known to be associated in the province:

Archean sedimentary rock—Iron-ore, manganese-ore, slate, quartzite, ochre.

Granite-gneiss—China-clay, building stones, road metal.

Pegmatite veins—Mica, felspar, beryl, rose quartz.

Other veins in Archeans—Graphite, lead, quartz.

Cuddapah system—Limestone, clay-shale, sandstone.

Gondwana system—Coal, fireclay, china-clay, sandstone, ochre.

Laterite—Building stone, bauxite, lithomarge, iron-ore, manganese-ore, ochre.

Alluvium—Kankar, brick and potter's clay, sand, gold, iron-ore, manganese-ore.

In India, the Archean sedimentary rocks are usually the host of the majority of mineral deposits. Little is known about the extent of these rocks in Orissa; according to the old maps they would appear to be relatively scarce in the province, but during the brief period since the recent survey commenced it has become apparent that they are rather more widely distributed than the old maps would suggest. Future work will indicate to what extent they are mineral-bearing. It is likely that they have been highly metamorphosed over a large part of this region. The iron-ores and manganese-ores are, perhaps, the more important deposits usually found in these rocks elsewhere in India.

The china-clays in the granite-gneiss have been formed by the alteration of the latter. Such alteration may have been originally deep-seated, but in some cases it is superficial and due to weathering. The granitic rocks provide, in places, excellent building and road-making materials.

The pegmatite veins are related to the granitic rocks and penetrate both these and the Archean sediments. Whether any valuable mica deposits will be found in Orissa is doubtful. Beryl and rose quartz have been found in pegmatite in Sambalpur and Angul. Felspar which occurs in most of these pegmatites may, perhaps, find a use later in ceramics.

The graphite, lead and quartz veins which occur in the gneissic rocks are all possibly related to the granitic intrusives.

The Cuddapah group is remarkable for its widespread limestones; some are of excellent composition and suitable for cement manufacture. The sandstones of this group are also widespread, and useful as building stones and perhaps also as abrasives.

The Gondwana system has quite a good potential value in Orissa, containing deposits of coal, fireclay, china-clay, ochre, and building materials, all of which will undoubtedly be more extensively worked in the future.

Laterite is widely used in Orissa for building purposes. Much of the iron-ore and manganese-ore is of a lateritic type. Bauxite has been reported from the high-level laterites of the Eastern Ghats, and recently from the summits of several hills in the Khariar highland in the Sambalpur district.

Alluvial deposits here include not only river clays and sands but also surface soil, and detrital material shed down hill-slopes. Amongst the latter are detrital iron-ores and manganese-ores shed from adjacent deposits. The most widespread use of the alluvium is for building purposes, providing lime, brick-clays and sand. Gold washing is carried on in a small way along some of the rivers in Sambalpur. Koraput and Angul.

Distribution according to districts

The mineral occurrences which have so far been examined are distributed as follows, according to districts:—

Balasore—This district has not yet been examined and little is known about it geologically. It is mainly covered by coastal deposits.

Cuttack (including Angul)—Building-materials (building stones and *kankar*), fireclay, china-clay, ochre, coal, gold, graphite, iron-ore, mica, steatite.

Ganjam—Building-materials (building stones and *kankar*), china-clay, manganese, mica.

Koraput—Building-materials (building stones and *kankar*), china-clay, ochre, gold, graphite, iron-ore, limestone, manganese.

Puri—Building-materials (building stones and *kankar*), fireclay, china-clay, ochre.

Sambalpur—Bauxite, building-materials (building stones and *kankar*), fireclay, china-clay, coal, gold, graphite, iron-ore, lead-silver, limestone, mica, ochres.

Future search for minerals

The geological information available is insufficient, as yet, to serve as a basis in guiding future prospecting for minerals in Orissa. Whatever advice that can be given must be of rather a negative character. It is, of course, apparent that within the alluvial zone of the coastal belt only such materials as *kankar*, brick clays, sands and laterite may be expected, as, except for a few isolated outcrops, the older rocks have been completely blanketed by the alluvium. Coal cannot possibly be expected outside of the basins of Gondwana rocks.

It would be unwise to assess the possibility of finding valuable mineral deposits within the province. In the past, Orissa has been regarded as a region particularly lacking in useful minerals, but the recent finding of iron-ore and manganese deposits has made more hopeful the future possibilities as the country becomes opened up.

In India, minerals have been found in one of three ways in the past: by the Geological Survey of India, by casual finds of villagers brought to the notice of those interested in minerals, or by organised prospecting departments of large companies.

Large companies have little interest in Orissa as yet, but if useful mineral deposits are found they will certainly attract greater attention to this province. One of the main functions of a geologist to an industrial concern is the prospecting of mineral leases which he can examine foot by foot in great detail. The function of a Government geologist cannot normally be that of a prospector, the area which he has to cover is too vast for the detailed work necessary in prospecting to be usually possible. During the course of his mapping, however, mineral deposits may be found, or local villagers may draw his attention to them. The primary function of the Government geologist, mapping, apart from the accompanying fortuitous finding of minerals, enables him to advise on and guide to limited areas the prospecting efforts of others. Once an industry has been established it also becomes one of his functions to assist that industry in the conservation of its resources and guide it in its mining. In addition his advice may be sought on many other lines of enquiry, some of them not related to mineral deposits, such as have been enumerated in Chapter IV.

Future geological mapping by the small staff of Government geologists available will be necessarily slow, as there is a vast area to cover and this must be done systematically. If the rapid finding of new minerals is the desideratum, much could be done by local officials in encouraging the villagers to search for and bring to notice new mineral finds. Payment of a small bonus to the villagers concerned, for such finds as may prove of economic value, may be an excellent stimulus for an energetic search throughout the province. In view of its greater importance from the point of view of accessibility, more particular attention should be paid to Ganjam and eastern Koraput. It must, however, be remembered that Orissa is in a backward state of industrial development, and it may not be possible to work for many years a number of the mineral deposits that may be found. This, however, will occasion no ultimate loss to the province, for, as industries gradually develop, more and more local raw materials will be used in manufacture within the

province, thus obtaining the maximum value from raw materials which otherwise might have been exported.

Bauxite: Bauxite deposits have not been actually located in the high-level laterites of the part of the Eastern Ghats within Orissa, but the fact that deposits occur in Kalahandi State provides some hope that workable deposits will be found on the highlands of Koraput, and perhaps Ganjam. Within Orissa proper the nearest approach to bauxite is a variety of aluminous laterite, deposits of which have recently been found on some of the hilltops in the Khariar highland in the Sambalpur district.

Building stones: The accessible building stones are sufficiently well-known and require no particular prospecting. Some of the rocks in Orissa, which take a high polish, such as the charnockites, could be used as attractive ornamental stones. They would be much more expensive, however, than the usual building stones, and it would be necessary to cultivate in the local population an aesthetic appreciation of the attractive qualities of these rocks.

Clays: The fireclay deposits will undoubtedly be developed gradually, but at present it seems more probable that these clays will be sent out of the province for manufacture and will not be worked up locally. However, much will depend on the development of industries which require refractories for furnaces. Prospecting for these clays will be restricted mainly to the Gondwanas.

There are quite a number of china-clay deposits, many of them apparently small but when opened up some of them will prove to be more extensive. Others will certainly be found in the future, more particularly within the granite-gneisses. Some of these clays could undoubtedly be used in white pottery and porcelain, others for paper and textile filler. The main difficulty is that the majority of the better deposits occur in Sambalpur, from where transport costs would be considerable to any works on the more densely populated sea-board.

Coal: The coal deposits of the Rampur basin in Sambalpur will undoubtedly be further developed. It is estimated that there are 100 million tons of fair quality non-coking coal available, and as mining on the field expands and the seams become better understood these reserves may be increased. That part of the Talchir coalfield within Angul does not appear to hold out hopeful prospects, the 5½-foot seam is not of good quality and thins rapidly. The possibility that coal-measures occur below the Upper Gondwana sandstones which crop out south of Cuttack can only be tested by extensive and expensive deep boreholes. Prospects in the Khondmals are not yet known, but do not appear to be bright.

Glass sands: River sands are not normally sufficiently clear to be used for better quality glass, but are used for glass bottles, etc. Sands of suitable quality may be sought amongst the friable sandstones of the Cuddapahs and Gondwanas.

Graphite: Poor deposits of graphite are known in Koraput and Sambalpur, and others of better quality are known in adjacent States, such as Athmallik and Patna. Further deposits may be found within the Archean rocks, more particularly in the khondalite tracts.

Iron-ore: The small deposits of iron-ore which occur in all parts of the province have no value on modern standards in India. The deposit of 10 million tons of high grade ore which occurs at Hirapur Hill in Koraput is too inaccessible to be used at present, and the same may be said of the 40 million tons of fair grade ore in Sambalpur. Should a deposit be found in the Eastern Ghats, closer to the coast, the position would be different. The geology of the Eastern Ghats region does not prohibit such a possibility, but it would be unwise to regard such a find as probable.

Limestone: Extensive deposits of good quality limestone are known in Sambalpur and Koraput, both suitable for the manufacture of cement. The former district would have to compete, however, with limestone used for the manufacture of cement in adjacent States and in other provinces, whilst the Koraput deposits are too inaccessible. The coastal side of the Eastern Ghats may contain deposits of limestone, but the possibilities are no higher than for iron-ore.

Manganese: The deposit at Kutingi in Koraput district is undoubtedly a valuable asset and will be worked in the future. It raises the possibility that other deposits may be found in the Eastern Ghats, in both Ganjam and Koraput, during future survey work.

Mica: None of the deposits of mica which have so far been found in all the districts of the province are of economic value. Either the mica is badly stained and strained, or the deposits have been very small. There is little doubt that the pegmatites in the mica-schists and gneisses of Orissa must be classed as potentially mica-bearing but the possibilities of finding profitable deposits seem to be very slight.

Ochres: Apart from the three deposits of ochre in Koraput and possibly a few in Angul, the ochres so far seen in Orissa are only suitable for local colour-washing of village huts as the standard of colour is not equal to that usually acceptable to the paint industry. The majority of these ochres are associated with the Gondwanas and laterites, but the Archeans are also likely to yield ochres, siennas and umbers, particularly in the areas of iron-ores and manganese-ores. Some of these pigments may yet find a use should a pottery industry arise.

Sillimanite: No deposits of this valuable refractory mineral are yet known in Orissa, but the sillimanite-quartz-rocks of the khondalites should be carefully prospected, as it is with such rocks that deposits of massive sillimanite may be expected.

Whether deposits of other minerals may occur in the more inaccessible parts of Orissa cannot be foreseen, information is as yet too scanty to serve as a guide.

CHAPTER VI

RENTS AND ROYALTIES

A considerable proportion of Orissa is zamindari land. From this Government will obtain neither rents nor royalties for such minerals as may be mined, but the province will gain by the employment of labour

and from increasing industrialisation. It must be emphasised that mineral deposits are wasting assets, resources lost through inefficient mining or treatment can never be recovered, and ultimately the State is the loser. Accordingly, control over the working of mineral leases should be as careful in zamindari as in *khasmahal* land. A uniform policy of rent and royalty payments should be enforced throughout the province.

The determination of the amounts of rents and royalties to be charged should be founded on a knowledge of the various factors which may affect the particular industry. The object, in principle, is to obtain the maximum revenue which will not, however, bear unduly heavily on the miner and prevent his efficient working of the mineral deposit.

In most cases rents are payable in two parts: (*a*) dead rent payable for the area of the mining lease itself, and (*b*) surface rent payable on land occupied by works, offices and quarters.

Usually dead rent must be regarded as a minimum royalty, as only whichever is the greater, dead rent or royalty, is payable in any one year. For iron-ore the minimum dead rent is one anna per acre, for coal, bauxite, pyrites and alkali salts four annas per acre, and for all other minerals a minimum of one rupee per acre. Surface rent is a fixed amount dependent on the actual local value of the land occupied, and assessable under the revenue and rent law.

As a general rule it may be said that in the first year or so of opening up a new deposit the dead rent will be paid, whereas later, when the deposit is worked vigorously, royalty will be the main source of revenue to the lessor for the deposit. The amount of dead rent payable should not be so excessive as to hinder working, and it should vary according to the type and size of the individual deposit. Some minerals may have a low market value and may be in small pockets scattered over a wide area—evidently in such a case the dead rent should be very low. In another case deposits of a more valuable mineral may be scattered over an equally wide area, when a somewhat higher dead rent is advisable. Yet again, a mineral of low value may be concentrated in a small area. so that a dead rent higher than in the first case is permissible, whilst if large reserves of a mineral of high value are concentrated in a small area, a commensurately high dead rent is legitimate.

Although it is advisable to keep the dead rent at a rate which will not hinder development, there may be the danger, if the rates are very low, of the deposits being taken up by inefficient concerns which have not the requisite capital to work the minerals vigorously. An inefficient and under-capitalised concern often means that the lessor is losing revenue on royalties which a more efficient company would have paid, and that ultimately large assets may be lost to the province because of wasteful working. Also, if the dead rent is too low, the tendency will be for the lessee to apply for a larger area than is really necessary.

The area covered by a mining lease will, of course, vary with the particular type of mineral deposit. In general, deposits like coal, iron-ore, limestone and copper require a considerably larger lease area than say china-clay, ochres and gold. In the case of a number of deposits

scattered over a fairly limited area, the lessee should not be permitted to take up a number of small leases leaving small unleased areas between, but should be compelled to take the whole, within reasonable limits.

Minerals in the ground are amongst the State's important assets, but they are wasting assets, for once removed they can never be replaced. It is, therefore, the State's right to obtain a fair return for the sale of these assets, and the normal means of securing this return is by charging royalties on the mineral removed.

The value of a mineral varies according to different stages of its production: it has one value to the miner as it lies in the ground, another value on being brought to the surface (known as the pit's mouth value), and other values as it reaches various points of transport and ultimately the place of manufacture where it is to be converted into finished articles. The increase in value depends on labour costs, transport charges, etc., through various stages. Theoretically, then, the value of the mineral *in the ground* is the difference between the sale price of the raw material and all labour and other charges from the moment of commencement of mining it. This value may be regarded as divisible into two parts: the value to the State, which is in other words the royalty, and the additional value to the miner, representing the latter's profit. That is, royalty represents the State's selling price of a mineral in the ground.

The difficulties of calculation of this theoretical value have led to simpler methods of assessment, but the methods to be adopted in charging royalties, and the amounts, give rise to difficult problems, for there is no consistent basis of determination which may be regarded as equitable for all deposits. Under the Mining Rules in the past, apart from the special rates of 5 per cent for coal, 7½ per cent on the annual profits or 2½ per cent on the gross value for gold and silver, one anna per ton for iron, and 30 per cent of the annual net profits for precious stones, the general basis of assessment of royalty for most minerals has been 2½ per cent of the 'pit's mouth' value of the mineral, but a flat rate has been commonly substituted for some minerals. The amount, 2½ per cent, is presumably based on past experience of what industry can afford to pay, compatible with Government's revenue requirements, but this cannot always be accepted as an *a priori* reason for future levies at the same rate.

Before proceeding with this discussion it is advisable to define some of the terms used.

By "pit's mouth" value of a mineral is meant the market value of the mineral, less transport and other charges incurred subsequent to despatch of the mineral from the mine.

The geologist imposes a definite restriction on the use of the term "ore", which is not always appreciated. An ore is a mineral aggregate containing a sufficient percentage of *metallic* constituents permitting it to be economically mined, treated, and marketed. The term is not applied to non-metallic mineral aggregates like sand, clay, talc, mica, which are not mined for any metallic content. It will be noted that the use of the term "ore" implies "grade"; if the grade is lower than that at which a profit can be made then the mineral is not, strictly, ore. Sometimes

an ore is divided into several grades, called, for example, first, second, and third grade ore, according to whether the quality is high or lower.

Obviously, then, royalty should be charged only on ore in the case of metallic minerals, and, in the case of others, on that material which it is payable to work. In general terms, royalty should be charged only on the product which is actually despatched from the mine for marketing.

The iron-ore of Bihar may be quoted as an example of the points which must be taken into consideration in determining royalty.

In Bihar the percentage limit for iron-ore is about 60 per cent iron—below that grade this type of ore cannot, in this country, be economically smelted. Included in these deposits there are large amounts of loose fine material which cannot as yet be economically treated in this country, although it can be used in other countries. Such fines are, however, piled at the mines for use in the future, and are not, therefore, wasted. Although these fines must be mined along with the solid ore, they are not despatched from the mines and are correctly not subject to royalty. In the early days of iron-mining in Bihar a low rate of royalty, one anna per ton, was fixed in order to encourage the industry. Now that this is well established a higher royalty may be charged. However, in view of the fact that equally high-grade ore is available in adjacent States, some of which ore may be better suited to certain purposes, an excessive raising of the royalty rate might lead to an extensive transference of mining from Bihar to the States. Although the simplest method of levying royalty is at so much per ton of ore, the more equitable basis would be on the average iron-content of the tonnage despatched for treatment, but actually the grade of ore despatched varies little.

Certain forms of soft or powdered iron-ore may be used for other purposes, such as for desulphurising coke-oven gases or for the manufacture of special paints. Such materials should not be treated on the same basis as iron-ore smelted for iron, as they may be sold for a higher price and should, therefore, be subjected to a higher royalty.

In the case of other ores, such as manganese, there may be a wide variation in composition or grade of the ores mined, and it would not be equitable to charge a flat rate of royalty for all grades of each mineral. The alternative then is to charge a separate rate of royalty for each grade of ore, first, second or third grade as the case may be, or charge the royalty on so much per unit of metal in the ore. The latter is certainly the most equitable basis of calculating royalty, but it occasions a considerable amount of trouble in checking mining returns and analyses.

The market price of minerals varies from time to time. If the royalty is charged at a flat rate Government is not receiving an equitable return when the price is high, and the miner may be subjected to a heavy burden when the market price is low. In the case of minerals on which the royalty is $2\frac{1}{2}$ per cent of the pit's mouth value, the royalty will vary according to the market price, but, on account of the inconvenience and labour involved in assessing these rates of royalty, a sliding scale is often adopted in which the royalty varies periodically with the market price.

It will be seen, therefore, that the method by which royalty is to be charged should be considered separately for each type of deposit.

Certain minerals such as iron-ore do not normally vary widely in value and for them a flat rate is a simple and reasonably equitable method of assessment. For those in which the valuable constituent is subject to wide fluctuations in price some form of sliding scale is equitable.

Some provision should be made in the terms of each lease for a revision of the royalty rate periodically, as the status of an industry may alter. When an industry is in its infancy low royalties form a desirable encouragement, but once the industry is well-established and as its ramifications extend, the lessor is entitled to an increased share in that industry's prosperity. Or, again, a local mining industry may suffer adverse changes in consequence of competition by overseas mines. At the same time, the basis of royalty charges should be as uniform as possible throughout India, otherwise an undesirable competition between provinces may result.

Some actual royalty rates may be quoted in order to illustrate how these vary from place to place.

White clay: Bihar, Re. 1 per ton of refined clay when the pit's mouth price is Rs. 20 or under per ton, *plus* an additional royalty of 20 per cent of the amount by which the pit's mouth value exceeds Rs. 20 per ton; annas twelve per ton for crude clay.

Coal: Bihar, 5 per cent on the sale value at the pit's mouth with a minimum of two annas per ton. For coal dust, half the rate fixed for coal.

Iron-ore: Bihar (up to 1938), one anna per ton if the tariff value of imported pig iron is not greater than Rs. 65 per ton, and one anna per ton more for every Rs. 15 or part thereof by which the tariff value of the iron exceeds Rs. 65 per ton. Since 1938, four annas per ton is being charged.

Limestone: Bihar, 9¾ annas per ton for a quarry within 5 miles of a public railway station, six annas per ton if within 5—15 miles of a railway station, four annas ten pies if more than 15 miles from a public railway station. Central Provinces, four to five annas per 100 mds., according to locality. Gangpur, six annas per 100 cu. ft.

Manganese: Bihar, twelve annas per ton for high grade ore (47 per cent Mn and over), or 10 per cent of the pit's mouth value when the price is Rs. 10 or under, subject to a minimum of nine annas, *plus* an additional royalty of 20 per cent of the sum by which the pit's mouth price exceeds Rs. 10 per ton and an additional royalty of 10 per cent of the amount by which the pit's mouth value exceeds Rs. 20; six annas per ton for low grade ore. Keonjhar, six annas per ton for manganese-ore and four annas per ton for manganiferous iron-ore. Central Provinces, five per cent; Mysore, ten annas per ton.

Mica: Bihar, no royalty is charged, but leases in the Kodarma Reserved Forest are at the rate of Rs. 12 per acre, each lease covering 40 acres. This method of assessment would be rarely applicable elsewhere, and some royalty rate such as 5 per cent may be applied.

From time to time it may be advisable for Government to consider levying other taxes on the mineral industry, such as on the finished product. In some cases the industry may be well able to afford such

tax, but in others such taxes may even go so far as to destroy the industry. The trade in some minerals has remarkably wide ramification and may be affected by conditions in widely distant parts of the world; these must be appreciated whenever taxation in any form is to be considered.

The above points have been discussed in very general terms, as the object has been not to lay down rules, but merely to outline the factors to be considered in determining rents and royalties. Every mineral deposit deserves separate consideration to obtain as balanced an assessment as possible both on behalf of Government revenues and for the benefit of the industry's development.

In concluding this section, recent litigation suggests that a brief item of advice may here prove apposite to prospective lessees and lessors. Any lease agreement which permits the removal, from the surface or from under the surface of any mineral material, whether it be soil, gravel, rock, ore, or any other form of mineral aggregate, and which is to be used for any purpose whatever elsewhere, should state explicitly whether royalty is or is not to be paid on this material, or state that rent is to be regarded as payment in lieu of royalty. This will avoid all possibility of litigation, as there have been cases in which the presumed legal as against the true definition of the term "mineral" has been used as a basis for claiming or refusing to pay royalty on mineral substances removed from a lease.

CHAPTER VII

INDUSTRY AND GEOLOGY

Industrial development

It is not possible for Orissa to attain a degree of industrialisation based on its mineral resources, comparable with Bihar. But an appreciable development must be expected, and this will depend largely on the extent to which the province can itself absorb its own products. It is, of course, obvious that the greatest benefit will accrue to the province by making the maximum use of local raw materials in domestic industries.

The part which the State, as represented by Government, should play in expansion may need to be greater in such a province as Orissa than in more industrialised regions. The steps to be taken in the development of industry are outside of the sphere of the geologist's activities, but, as he is acquainted with the possible available resources, his advice on the direction which development should take may be cogent. The geologist's views must necessarily extend beyond the bounds of mineral resources only.

The first requirement before industrial enterprise is to be attracted is that a cheap supply of power should be available. The great industrial centres of the world have been based mainly on the ready supply of coal or oil, and in India expansion of industry in Bihar and Bengal has taken place side by side with the expansion of coal mining. Orissa, apart

from Sambalpur, is not so fortunately placed, but reasonably cheap power may become available in the future from hydro-electric schemes sited in the Eastern Ghats and from the multipurpose dam at Hirakud in the Sambalpur district. Unfortunately, hydro-electric power schemes have not the flexibility of power plants based on coal—the latter can be readily expanded from time to time as load requirements increase, the former require a much greater initial outlay and, once the load capacity is exceeded, completely fresh schemes must be developed. In general, coal power schemes have a low relative capital cost but high running cost; hydro-electric schemes involve a high capital expenditure and very low running costs, but the interest on capital is of course higher than in coal power schemes. If the capacity of a hydro-electric scheme, designed for an ultimate load in the distant future, is much greater than present load requirements then a large amount of capital is tied up, idle. Still, by careful layout of reservoirs, weirs, and power stations, it is often possible to design quite a flexible hydro-electric scheme, capable of expanding gradually with increased load requirements within limits, and without any great change in the initial scheme, thus keeping the capital costs to a reasonable figure within each step of development.

Two opposing views arise : the engineer desires to know what load will definitely be required before designing a scheme. The industrial promoter looks around for areas in which power is already available cheaply—unless he can find it he goes elsewhere. As this problem determines whether or not an area is to industrialised rapidly it may be for Government to decide whether the risk should be accepted and hydro-electric power developed. A second requirement of industrial development is facility of transport. One of the unfortunate features of Orissa is the comparative isolation of Sambalpur and Koraput. A railway connection from Sambalpur to the coast *via* Talchir, may assist in the more ready interchange of commodities within the province.

In surveying the list of possible minerals which may be developed, it must be remembered that the natural outlet for the Eastern States and even the country further inland is towards the Orissa coast. Raw materials from these areas could be worked up in Orissa should facilities be available. For example, it is not improbable that bauxite of Kalahandi State could be converted into aluminium and alumina abrasives at works in Orissa, should sufficiently cheap power be obtainable. Graphite deposits which are known to occur in the Orissa States and in the Sambalpur district could be worked up into crucibles, lead-pencils, graphite lubricants, etc., in Orissa.

Within Orissa itself the pottery industry may be gradually expanded, using the china-clays which are known to occur in quite a number of places. Coal mining will presumably increase in Sambalpur as the market develops—this would almost certainly be accelerated were a rail connection made between Sambalpur and Talchir through Angul, a remark which might equally aptly be applied to other minerals available in Sambalpur.

Whether or not a glass industry could be established other than the manufacture of poor quality bottle glass, will depend upon whether cheap supplies of good quality silica sand can be found. Limestone of reasonable purity is available in Sambalpur, soda would need to be

imported. With this industry it may be possible to combine the manufacture of mineral wool, a heat insulating material for which a good market might be developed in India.

The smelting of iron-ore in Orissa is scarcely feasible at present, as the deposits are not very accessible, but should hydro-electric power become available improvements in technique may make possible the use of these ores for local requirements of iron and steel.

The limestones of Sambalpur are sufficiently accessible for use in the manufacture of cement, but unless a market could be found locally, competition with cement manufactured in other provinces would be a great difficulty. Limestones of suitable composition are available in large quantities in the Dungri limestone tract and cannot only supply the needs of the Mahanadi Valley Project, but also of a long-term cement industry in Orissa.

The manganese deposits of Koraput will be presumably exploited shortly for export *via* Vizagapatam, but some endeavour should be made to determine whether any of the ore could be utilized locally for, say, the manufacture of dry batteries, as a decoloriser in glass-melting, the manufacture of chemicals, or even for smelting ferro-manganese.

The use of ochres and other pigments in Orissa is restricted by the poor quality of most of the known material. There seems little possibility of a paint industry arising, but these pigments could be used in any pottery works that may be established.

The development of an industry in refractory materials will depend on industrial expansion in other directions, such as in the manufacture of cement, iron and steel, paper, etc., in which furnaces require the use of good quality refractory materials. Such materials are available in Orissa when necessary.

A close enquiry may be made into the possibility of expanding the manufacture of salt in Ganjam. The present tendency appears to be towards a reduction of output. The production is confined to the requirements of the local market. The salt produced is coarse and crude, and no refined salt is manufactured. It is remarkable that the salt industry in this locality has not expanded to the extent of supplying not only the requirements of Orissa but also much of the Bengal market. Salt manufacture may ultimately form also the basis of a local chemical industry, for the manufacture of hydrochloric acid, chlorine, bleaching powder, alkali, etc. It seems to the writer that modern technical development of the salt industry along the Ganjam coast is more likely to yield widespread results than perhaps any other mineral in Orissa.

Geological research in Orissa

The lines upon which future prospecting may be undertaken in Orissa, have already been indicated. But mineral investigations form only a part of the work of geologists, and in Orissa there is scope for practical geological research which will be of benefit to the province.

The work of officers of the Geological Survey must be of a broad nature, and they must necessarily take an interest in all phases of geology. The basis of the Survey's work is the detailed geological mapping

of the country and from this springs its ability to give expert advice on such matters as prospecting, development of mineral industries, problems affecting the relation between Government and the mineral industries, water-supply, and geology as it concerns such engineering problems as structural foundations and building materials, and soil surveys.

In Ravenshaw College, Cuttack, there is no course in geology, nor would the writer recommend the establishment of a full course on this subject, for the province is scarcely likely to offer any livelihood to a number of geologists. Still, from the educational point of view, geology up to a reasonable standard should be taught as part of certain University courses. It would be possible for the teachers in this subject to carry on geological research within the province. There is a great need for a detailed study of the development of the physiographical structure of Orissa, and this could be done by University workers in vacation periods. It would help to provide invaluable information on river movements and flooding, and on soil erosion. The geological aspects of soil surveys and soil erosion could be investigated also by University workers, but these problems must necessarily be studied in great detail.

The general study of underground water throughout the province, and more particularly in the coastal belt of recent deposits, is desirable. This would include the compilation of an immense amount of detail concerning all tube wells put down, so that eventually the useful water horizons will be understood. Such work could be readily carried out by University workers, but continuity of study is imperative hence it must be undertaken by a permanent officer.

Part II

THE RECORDED MINERAL OCCURRENCES OF ORISSA

(By Mr. A. M. N. Ghosh, Drs. B. C. Roy and A. K. Dey, and Mr. G. C. Chaterjee under the superintendence of Dr. J. A. Dunn)

CHAPTER VIII

ABRASIVES AND GRINDING MATERIALS

General

An important requirement of almost all phases of industry is the use of materials for cutting, abrading, polishing, crushing, and grinding. These may be used as powders of all degrees of fineness, as cutting or grinding wheels, or as pebbles in grinding mills for paint, clays, etc.

The natural or mineral abrasives have been considerably replaced by artificial products in recent years, particularly for metal work. The manufacture of artificial abrasives has become an industry of great importance, but one which has scarcely found a footing as yet in India, notwithstanding the availability of the mineral raw materials for its establishment.

The most essential property of an abrasive is hardness, as it is on this that the cutting or abrading power of the material depends. With this, however, must be combined toughness, for the effect of hardness will be annulled if the material breaks up readily under the shattering action of the process of abrading. At one time the classification of hardness of abrasives was based on Moh's scale, in which minerals were graded from 1 (talc) to 10 (diamond), the harder minerals of this classification being felspar (6), quartz (7), topaz (8), corundum (9), diamond (10). The interval between each number of this scale did not by any means represent equal differences in degree of hardness. With the widespread use of artificial abrasives in recent years, this scale has been extended to quartz (8), topaz and garnet (10), corundum and tungsten carbide (12), silicon carbide (13), boron carbide (14), diamond (15). There is still no artificial compound harder than diamond, but the latter's rarity restricts its use.

Natural abrasives

The natural abrasives are classed into "High grade natural abrasives and "Siliceous abrásives".

The "High grade natural abrasives" include diamond, corundum, emery, and garnet as the principal minerals. Of these diamond is very rarely found in Orissa, corundum and emery are so far unknown in the province and only garnet is likely to occur in quantities sufficient to be used as an abrasive. Garnets are known to be particularly abundant

in the rocks of the Eastern Ghats and will probably be found concentrated in places along the stream beds. At Banapur (19° 53′: 83° 27′), in Koraput, garnets are found in surface detritus, and near Mudepala (20° 07′ : 82° 45′), in Nawapara subdivision, Sambalpur district, loose garnets are found abundantly in the *nalas*. There is no market for garnets in India at present, and none is likely to be found unless an abrasive industry, which includes the manufacture of garnet-paper, is created in India.

The "Siliceous abrasives" comprise the various forms of free silica, quartz, sand, sandstone, quartzite, flint, chert, tripoli, diatomite with also various materials which depend on their quartz or silicate content for their abrading properties, such as silt, siliceous shales and clays, siliceous limestone, pumice, volcanic dust, rotten stone, felspar and granite.

Sands are used for cutting, polishing and burnishing. For this purpose either river sands may be used or friable sandstones which may be readily crushed. In Orissa, most of the river sands are rather too coarse for this purpose and would need to be further ground. Friable sandstones of Cuddapah or Gondwana age may later be found suitable after crushing and sieving. Sands are also used for the manufacture of sand-papers, and for this purpose crushed and graded quartz, either from river sands or quartz veins, is suitable.

The milder abrasives such as pumice, volcanic dust, tripoli, diatomite, china-clay, chalk, lime, talc, and ground felspar are used generally in powdered form for putting a finishing surface on wood and fine metallic instruments, or for such domestic purposes as scouring and cleansing. Of these materials, pumice, volcanic dust, tripoli, diatomite and chalk are not available in Orissa. The province's resources of china-clay are described in Chapter XI, lime in Chapter XVII, talc in Chapter XXIV, and felspar in Chapter XXIV, and for abrasives of this nature the province is well-provided should at any time an industry for the marketing of these powders be established.

Sandstones of a fine-grained even texture are used as grindstones, sharpening hones, and as millstones. These may be obtained more particularly from amongst the Cuddapah sandstones and Gondwanas—the latter are worked near Khandgiri 20° 16′ : 85° 47′ and Nayapali 20° 17′ : 85° 49′ in Khurda subdivision, Puri district.

Quartzites may be used as millstones and sharpening hones, provided they are fine-grained. Quartzites of this quality are found amongst the Archean rocks, and in the Cuddapahs of Sambalpur district. Extensive deposits of cherty and porcellanoid rocks occur near Makerchua (20°35′ : 82° 35′), Jharnamal (20° 25′ : 82° 37′) and Khajuria (21° 31′ : 83° 36′) and may find a use as hones or sharpening stones.

Pebbles of flint, chert or fine dense quartzite find a use in mills for grinding limestone, cement, ore, paint, clays, etc., although nowadays they have been largely replaced by steel balls. However, particularly in pottery work where contamination with iron must be avoided such pebbles are still used. Pebbles from the streams draining the above-mentioned cherts, and porcellanite in Sambalpur district may be used for this purpose.

Artificial abrasives

The manufactured non-metallic abrasives which are now on the market and imported into India are: (1) Silicon carbide (*i.e.*, carborundum, (2) fused alumina (*i.e.*, alundum) and (3) boron carbide (Norbide). Their manufacture depends on the availability of cheap sources of power, and this is usually associated with hydro-electric schemes.

Should such power be made available in Orissa, it would not be difficult for either silicon carbide or fused alumina to be made in the province. Silica is available in the form of quartz sands, and alumina as bauxite is known to occur in the Eastern Ghats. There seems no reason why such an industry should not be able to market its product even overseas, in competition. say, with American products.

Future

The scope in Orissa for the utilization of such materials as sand, clay, lime, talc, felspar, in the powder form as abrasives will depend largely on the general development of such industries in the province as will require the use of abrasives. With the introduction of artificial grinding wheels the use of sandstones, quartzites, etc., as grindstones is likely to diminish, although their use in millstones may continue. In view of the rapid growth of industry in India the possibilities of the establishment of an artificial abrasive industry may well repay investigation.

CHAPTER IX

BAUXITE

General

The name "bauxite" was given to a peculiar clayey substance which contains a very high percentage of alumina and water, some ferric hydroxide and a comparatively small percentage of silica and other impurities. In India it is a variety of laterite which may be relatively free from ferric hydroxide, and is associated with many of the more normal widespread laterites. Such laterite has been found capping plateaux of the Eastern Ghats.

There has been a certain small annual production of bauxite in India, but the deposits of the Eastern Ghats have not been utilized.

Uses

The industrial applications of bauxite are numerous. Perhaps its most important use is as a source of aluminium. Electrolytic separation of aluminium from alumina obtained from Indian bauxite, is now carried

out at the Aluminium Corporation of India's factory at Jaykaynagar, near Asansol and also at the works of the Indian Aluminium Company at Alwaye, North Travancore.

Bauxite can be manufactured into a high quality refractory brick for furnace linings and it is also the raw material for the manufacture of certain alumina abrasives, which are used as grinding powders or made into grinding wheels, etc. It is also now widely used in the manufacture of aluminium sulphate and other aluminous salts. Certain commercial products, known as "alumino-ferrite" and "alferite", are prepared by digesting crude bauxite with sulphuric acid and are used in the preparation of all but the finest papers, in the precipitation of sewage and refuse liquids, and in the clarification and decolourisation of water-supplies. The aluminium salts are directly used in the chemical industries, in dyeing, tanning and printing. Aluminium chloride has been recommended for the preservation of wood, whilst an impure chloride containing also calcium and sodium salts is a disinfectant. The quick-setting properties of alumina cement, *cement fondu,* have long been known; experiments have recently been made in India for the preparation of alumina cement from local bauxite and limestone.

Most of the ore produced in India, to date, has been used by the oil companies for the purification of kerosene.

Classification

For commercial purposes bauxites may be classified into the following varieties:

(A). *Normal bauxite*—High grade ore with over 60 per cent alumina and fair quality ore with 55 to 60 per cent alumina. Excluding combined water, total impurities should not exceed 20 per cent. The chief impurities, ferric oxide, silica and titania, each should not exceed 5 per cent.

(B). *White or siliceous bauxite*—Contains upwards of 55 per cent alumina and not more than 20 per cent impurities excluding combined water. Silica from over 5 to about 20 per cent. Ferric oxide less than 5 per cent. Titania up to 5 per cent. This class of ore is most frequently used for chemical purposes and the preparation of alum or other aluminium salts.

(C). *Titaniferous bauxite*—The alumina should average 55 per cent and the total impurities, excluding combined water, should not exceed 25 per cent. Titania above 7 per cent. Silica less than 5 per cent. Ferric oxide should not exceed 10 per cent. These bauxites are rare except in India, but should prove valuable because of their titania content which it may be possible to collect as a bye-product if the Bayer process is used for treatment of the ore.

(D). *Ferruginous bauxite*—Alumina content should be near 52 per cent and the total impurities not greater than 25 per cent. Ferric oxide between 10 and 25 per cent. This variety of bauxite is that generally used for reduction to aluminium.

Some analyses of typical bauxites from the Eastern Ghats are given below:—

	A.	B.	C.	D.	E.
Al_2O_3	63·14	39·69	25·84	61·92	67·88
Fe_2O_3		2·24	8·86	4·44	4·09
SiO_2	19·32	45·14	53·93	2·30	0·93
TiO_2	...	trace	2·59	2·77	1·04
CaO	...	1·07	0·16	0·09	0·36
MgO	...	0·15	trace	trace	...
H_2O (at 106°C)	16·81	0·76	0·68	1·14	26·47
H_2O (above 106°C) ...		11·65	8·45	27·51	
Total .	99·27	100·70	100·51	100·17	100·77

A—Hill south-west of Girliguma (18° 33′ : 83° 00′), Vizagapatam. Analyst—T. H. Holland.

B—From southern end of Korlapat hill (19° 41′ : 83° 09′), Kalahandi State. Analyst—M. S. Krishnan.

C—From northern end of Korlapat hill, Kalahandi State. Analyst—M. S. Krishnan.

D—From Korlapat hill, east of Polangpodor, Kalahandi State. Analyst—M. S. Krishnan.

E—From Korlapat hill, Kalahandi State. Analyst—H. Warth.

Mode of occurrence

The surface rocks of the high plateaux of the Eastern Ghats have been subjected to sub-aerial alteration over a prolonged period of time, and this alteration, in a tropical climate of alternating wet and dry seasons such as in India, has resulted in the formation of laterite, a hydrated oxide of iron and alumina, the greater portion of the silica and other constituents, apart from titania, having been removed in solution. The underlying rocks thus become covered by a capping of laterite, probably averaging 30 feet in thickness, but may vary considerably, depending on local contour and rock variations around and on the plateaux.

On studying sections across such laterite plateaux elsewhere it has been found that certain well defined layers may be distinguished between the surface and the unaltered rock below. At the surface there is commonly a thin layer of red or yellow clay, but this is frequently absent, particularly around the scarp-edge of the plateau, and the underlying layer of hard ferruginous laterite may be exposed. This layer is of variable thickness, but 1 to 8 feet is most usual. Along the scarp-

edge of the plateau this hard laterite is normally pisolitic in structure. Immediately below this hard layer of ferruginous laterite there is a layer of bauxite varying considerably in thickness, generally from 8 to 24 feet, but always thickest at the edge of the plateau scarp or below any stream depressions on the plateau surface, and completely thinning out laterally towards the centre or higher parts of the scarp. At the extreme edge of the plateau, along the scarp, the bauxite, like the ferruginous laterite, is commonly pisolitic in structure. Below the bauxite and immediately below the hard laterite in the centre of the scarp, there is a zone of soft porous laterite, usually 12 to 30 feet in thickness and extending down to ground-water level. Underlying this is a zone of laminated siliceous lithomarge, from 6 to 20 feet in thickness which may provide a useful clay. This overlies kaolinised rock which may be 40 to 60 feet in thickness before the unaltered rock is entered.

This orderly arrangement is the result of unchanging conditions of rock alteration, drainage, and seasonal sequence over a prolonged period of time. Below ground-water level kaolinisation of the rocks is taking place. Above ground-water level the more soluble constituents, such as silica, are carried downwards either in solution or as colloids, leaving this zone higher in alumina. The iron hydroxide is either drawn to the surface by capillarity during alternating dry seasons, or remains in the lower part of the zone, so that between the two layers of laterite the zone becomes impoverished in iron and increasingly rich in alumina. The alumina itself forms a gel which separates out on the outer scarp face of the leached bauxite layers as pisolitic bauxite. The actual chemical processes involved form a difficult and perhaps, as yet, uncertain study.

Localities

Although laterite occurs extensively over the Province and in the Eastern States, the known occurrences of bauxite are very few.

According to Dr. C. S. Fox, bauxite is reported to occur in the laterite which caps the hills of the Eastern Ghats in northern Koraput district but no details have been recorded and the only locality given is Girliguma hills, south-east of the village of the same name (19° 07′ : 82° 55′), where a somewhat siliceous, lateritic bauxite occurs; and Dr. Dey records the occurrence of some small boulders of ferruginous bauxite near the base of a laterite plateau north of Manduru (19° 56′ : 83° 33′).

Mr. S. C. Chakravarty came across insignificant patches of aluminous material in the superficial laterite on the flat-topped hill of Nagasari Estate forest, about five miles N.N.W. of Padwa (18° 22′ : 82° 41′) in the Koraput district.

Dr. A. G. Jhingran has located high-level aluminous laterite on the summits of several hills in the Khariar highland in the Sambalpur district. The most important occurrences are at Barepat Dongar (20° 20′ : 82° 27′), Sainipara Hill* (20° 18′ : 82° 27′) and Kandamal Hills* (20° 16′ : 82° 28′). At each of the first two places the laterite is 30 feet thick and at the last mentioned locality it is over 50 feet thick.

* Local names not given in 1″=1 mile topo. sheet 64 L/7.

The following results were obtained in the laboratory of the Geological Survey of India from partial analyses of average samples from these hills:—

Locality.	*Depth from surface.*	Silica per cent.	Iron sesquioxide per cent.	Alumina per cent.
1. Barepat	4′3″	19·20	42·66	27·34
2. Sainipara	3′ to 5′6″	19·80	21·33	44·27
3. Kandamal Hill (Bara)	Surface to 2′	10·68	21·33	41·47
4. ditto. ..	2′6″ to 3′6″	13·04	19·78	50·05
5. From between the Bara and Chhota Kandamal Hills	4′3″ to 6′	12·12	7·11	60·49
6. Kandamal Hill (Chhota)	Surface	2·06	39·50	38·20
7. ditto. ...	2′ to 3′6″	5·90	30·44	49·06

From the above figures it will appear that the material from the Bara and Chhota Kandamal Hills is fairly rich in alumina. It may be added that a couple of feet below the surface there is a decrease in the content of iron sesquioxide and a corresponding increase in alumina. Sample No. 5 containing 60.49% alumina is from the low ground between the Bara and Chhota Kandamal hills.

The deposits lie nearly 6 miles from Kot (20° 15′ : 82° 32′) at the foot of the hills and about 40 miles from Harishankar Road station on the Raipur-Vizianagram section of the B.N.R. In Dr. Jhingran's opinion economic exploitation of the material may not be very difficult should the quality continue to improve at depth.

In the Eastern States, bauxite is reported from Korlapat hill, 3,981 feet (19° 34′ : 83° 14′), in Kalahandi State. The hill is a long flat-topped ridge capped with laterite, which extends for seven miles south of the village of the same name. The analyses of bauxite from Korlapat hill are so good (*see* page 32) that, if large quantities exist, the tract must prove important as the country is not very difficult eastwards towards the B. N. Rly. along the Nagavali valley.

Future

Although information of the bauxite deposits of the Eastern Ghats is very meagre, there seems little doubt that further occurrences will be brought to light in this widespread area of plateau laterites when it is mapped in detail. At the same time no picture can be provided of an extensive industry founded on such bauxite deposits. If considerable deposits are found and cheap hydro-electric power becomes available then the production of aluminium and alumina abrasives may be investigated in the future.

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CHAPTER X

BUILDING MATERIALS

General

Orissa is well provided with building materials of various kinds. Building stones are abundant, although the better types of stones, particularly those which are hard and would take a good polish, are rarely used, presumably because of their cost. Some excellent stones, such as the charnockites, which would be eminently suitable for the more ornamental purposes in building construction, are available in the Eastern Ghats, but cost of transport is likely to prevent their development for this purpose for many years to come.

Clays for the manufacture of bricks are found in the alluvium throughout the Province, although, in consequence of their rather sandy nature, the resulting bricks are usually not of the best quality.

Most of the lime used in the districts is obtained from surface deposits of *kankar,* or from beds of ghootin found along the coast. The bedded Cuddapah limestones may be found suitable, later, for the manufacture of cement and it is not at all improbable that limestone deposits will be found in the Archeans of the Eastern Ghats.

It may be judged, however, that any industry in building materials will depend upon Orissa's own demand. It will expand with the development of the Province, but little or no export trade can be expected.

Cuttack

(A. K. Dey)

Building stones

The common building stones of Cuttack are granitic gneisses, sandstones and laterite. The granitic gneisses are very little used in the Angul subdivision ; they are almost the only material available but there is little demand for them except for rough work. The Upper Gondwana sandstones developed along the Mahanadi river to the west of Cuttack town are used for all sorts of building purposes ; they are soft, durable, easily dressed and capable of being finely carved. Sandstone quarries at Naraj, on the bank of the Mahanadi about six miles west of Cuttack town, meet local demands for building stones and for cornices and other ornamental work. There are also quarries further west, as those of Pathpur and Ghasiput.

Laterite is not suitable for ornamental work, but provides a cheap building stone. It is easily quarried and dressed and hardens on exposure. Only the superficial laterite, to a depth of two or three feet, has the required hardness for building stone ; beyond this depth the rock is too soft. Laterite suitable for building purposes is developed over a large area to the north-east and south-west of Cuttack town.

Lime

In Cuttack, lime is made by burning shells collected along the coast, or *kankar* which occurs here and there in superficial deposits,

particularly on the banks of the Debnadi, to the south of Cuttack, or other rivers in the delta of the Mahanadi.

In Angul, besides *kankar* which is found in the surface detritus at various places, a kind of calcareous tufa or travertine, locally developed on the surface and in the crevices of rocks, is also utilized.

GANJAM

(G. C. Chaterji)

Building stones

The rocks generally used in this district for building purposes consist of (*i*) Khondalites, (*ii*) Quartzites, (*iii*) Garnetiferous granitic gneisses and (*iv*) Charnockites.

Many of the quartzites have developed a fine jointing and some of the khondalites, when partially weathered, open easily along their foliation planes. In consequence, these rocks split readily and are preferred wherever available. The pink colour of the khondalites is much appreciated locally and they have been used since ancient times for temples and other buildings. Being generally fine-grained they are susceptible to delicate carving, which is a feature of the Orissa temples.

Khondalites and quartzites are quarried at many places including Kukkudakhani (19° 23′ : 84° 45′), Nimmakhandi (19° 20′ : 84° 48′), Matiasai (19° 16′ : 84° 46′), Pedda Gumla (19° 20′ : 84° 50′), Gurunthi (19° 22′ : 84° 50′), Mollada (19° 26′ : 85° 01′), Garh Humma (19° 26′ : 85° 04′), Sontoshopur (19° 28′ : 85° 01′) and Lunguri (19° 26′ : 85° 03′).

The garnetiferous granitic gneisses and charnockites are used largely for bridge-building purposes and are also employed locally in the manufacture of grindstones. Their coarse granular texture and the readiness with which they split into massive slabs along gneissic planes make them very suitable for such purposes. Quarries exist near Khodasingi (19° 19′ : 84° 50′), Halidiapali (19° 17′ : 84° 47′), Bendalia (19° 17′ : 84° 46′), Jagadalpur (19° 21′ : 84° 47′) and elsewhere. Many of the lighter coloured charnockites, which take a good polish, would form very attractive building stones.

The dark coloured rocks, basic charnockites and diorites, pyroxene granulites and mylonites are avoided as building stones mainly because of their toughness and also to certain extent in consequence of their sombre colour. These rocks and the massive quartzites are, however, used to a considerable extent as road and railway ballast. The hillock near Tangonappali (19° 23′ : 84° 53′) would yield very good road metal.

The 1944 prices of dressed khondalite building stones in the plains are as follows:—

(i) 1½ ft. diameter pillars, As. -/6/- to As. -/8/- per foot.

(ii) Shaped rectangular blocks, As. -/8/- to Rs. 3/- per piece depending on the size.

(iii) Unshaped blocks and slabs, Rs. 2/- to Rs. 2/8/- per 100.

(iv) Rectangular mangers, size 3′×2′. about Rs. 4/8/- each.

Lime

Kankar and travertine, locally known as 'Ashurahada' (Giant's bone), are abundant at many places in the district. Sub-soil weathering of basic granulites and felspar-rich gneisses often produce very good *kankar* deposits.

*In recent years investigations have been made of a large number of *kankar* deposits in the plains as well as in the hilly areas of the district. Usually the exposures are small and the nodules are not uniformly distributed in the soil. The thickness of the *kankar*-bearing soil varies from an inch or two to nearly 6 feet at a few places. Where nodules occur in the soil, the percentage by volume of *kankar* hardly exceeds 5 per cent of the total and rarely reaches 10 per cent. Sometimes when the soil is eroded by rain water the nodules are left exposed and may either accumulate in layers up to a few inches thick as on the top of a mound or roll down the sides and collect at the base of the slopes as talus. Owing to the uneven distribution of *kankar* in the soil in these parts an average of 20 tons per acre has been assumed for estimating the reserves in the district. Calculated at this rate the largest *kankar* deposit so far examined appears to contain about 5800 tons of the material at Kurlanda Z.F. (Sitaghai) near Parlakimidi. Another deposit in the same area is of the order of nearly 4000 tons. Elsewhere in the district there are nearly a dozen other deposits with the reserves lying between 1000 and 4000 tons, while in the case of a few others, over two dozens in number, the reserves vary between 30 and 600 tons. Analyses of a few samples of *kankar* show the CaO content to range between 35·83% and 50·80% and the insolubles, mostly SiO_2, between 29·76% to 41·10%. Obviously small deposits of such poor material can only be locally used for the manufacture of lime as has been done hitherto. The *kankar* is burnt, using wood as fuel, in country made circular kilns with a capacity of about 24 to 47 cwts. of the material. A kiln is charged four times a month during the lime-burning season from January to April, but rarely does a kiln receive a continuous supply of nodules, fuel and water all the four months. Hence the operations are very much interrupted.

*In the Berhampur taluq lime is also obtained from burning marine shells collected by villagers from the sea-shore and the sandy stretches behind the beach or from the marshy area near Ekasingi, where similar shells occur in thin layers in mud 10 to 15 feet above the sea-level.

On the Patingia Soru hill near Gochhapara (80° 00′ : 20° 29′) in the Khondmals, a deposit of calcareous tufa was found accumulated on the face of a granitic gneiss exposure at the foot of a small waterfall. The local villagers have almost exhausted this surface accumulation of their supply of lime.

KORAPUT

(A. K. Dey)

Building stones

Gneissic granites, gneisses and charnockites are the principal building stones of Koraput. These are widely developed so that it is unnecessary

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* **Recorded by Mr. Y. G. K. Murty, Assistant Geologist, Geological Survey of India.**

to refer in detail to all the localities where they may be found. Generally. charnockites and khondalites constitute the main mass of the Eastern Ghats, the gneissic granites, gneisses and other types forming only a small proportion. In the country west of the Ghats, the gneissic granites and gneisses predominate. The charnockites have been long known for their excellent qualities as building stones and have been extensively employed in the construction of temples, forts, etc., in the Madras Presidency. They are strong, durable and can be quarried in blocks and slabs of any size. Charnockites occur in accesible places along the roadside near Koraput town, Jeypore and other places but so far they have been used only for road metal and in the construction of bridges, etc. The gneissic granites and gneisses vary greatly in character from place to place so that some caution is necessary in selecting those which are most suitable for building purposes. Over a considerable area the rocks are either schistose or so coarse-grained and biotitic as to be of no value for building. Non-schistose and finer-grained types which are found here and there, however, afford serviceable material. The khondalites make poor building material, for not only do they crumble easily, but the abundant garnets give the rocks a patchy appearance.

Laterite is accessible along the roadside south-east of Koraput town and in the Kotpad area, but hitherto little use has been made of it. Recently the district authorities have considered bringing a few artisans from Puri or Ganjam district with a view to teaching the local people the art of carving laterite, so that the material may be utilized.

Some slates of inferior quality are procurable from the Cuddapah formation cropping out on the hills about one mile east of Gupteswara temple (18° 49′ : 82° 10′). The cleavage in these rocks is not so strongly developed as to obliterate the lamination and the slates consequently split rather unevenly. Some of these slates appear to have been used in the steps of the Gupteswara temple.

Some purple slates of the Cuddapah formation occur to the north east of the Jeypore plateau, adjoining Kalahandi State. Some of the slates may be used for paving.

Deposits of steatite, which occur at many places in the Jeypore and Malkanagiri taluks, are also used to a small extent for building purposes. A deposit about half a mile west of Antigam (18° 52′ : 82° 32′) was formerly worked but is now abandoned and a deposit of chloritic and schistose steatite, about a mile W.N.W. of Majjiguda (18° 47′ : 82° 26′) is locally used for making milestones.

Dr. T. L. Walker mentioned the occurrence of red and white dolomitic limestone near Kondajodi (18° 57′ : 82° 15′) which would provide a very handsome marble, as it takes a high polish. Unfortunately, the railway is at a considerable distance.

Lime

In Koraput district lime is made from *kankar* which occurs locally on the surface. Occasionally, a calcareous tufa, found in the crevices of rocks, is utilized in lime burning. The limestone deposits near Kottametta (18° 20′ : 81° 42′), Gupteswara (18° 49′ : 82° 10′), Sirivada (18° 50′ : 82° 10′) and Kondajodi (18° 57′ : 82° 19′) have not so far been

used in any appreciable quantity in lime-making, for want of local demand.

The principal source of lime in the Rayagada subdivision is *kankar* which occurs here and there throughout the area. Deposits of calcareous tufa are found occasionally. One such deposit is found on the slope of a hill alongside a *nala* about half a mile S.E. of Dummaguda (19° 10′ : 83° 26′). The exposure measures about 60 feet in length.

Puri

(G. C. Chaterji)

Building stones

For building purposes laterites and sandstones are generally used in Puri district. Other rocks found in the district, such as khondalites, granite-gneisses, etc., are not favoured by the village masons as they are comparatively hard and tough when fresh. These hard stones have been used mainly as road and railway ballast. However, they are used as ornamental facings or as lintels in temples and other buildings, both ancient and modern.

The extremely compact quartzites are not worked by the local people and are called 'Akarmasila' or useless stone. On weathering some of the quartzites separate naturally into rough slabs and these, in an uncut and unshaped condition, are used as door-steps and for other domestic purposes.

Gondwana sandstones which crop out widely in Khurda subdivision yield excellent building material. They are grey and light red in colour. The red sandstone occurs over an extensive area in the region of Khandgiri (85° 47′ : 20° 16′) and Nayapali (85° 49′ : 20° 17′). Associated with clay beds in the Andharwa Protected Forest there occurs also a white sandstone which has been quarried for tile-making. The Gondwana sandstones have been extensively used as building stones since time immemorial in many of the oldest temples, such as the temple of Jagannath at Puri, the pinkish colour of some of these stones being locally much appreciated. The material has also been extensively used for making tubs, grindstones and other articles which are sold very cheaply.

Laterite is widely distributed in the district, especially near Bhubaneswar, and is extensively used for making culverts, huts, temples, palaces, and even for road metal. Its great advantage is that it can be cut easily into blocks and, when subsequently left exposed to the atmosphere, it hardens and becomes quite tough and resistant. The usual size of the blocks is three quarters of a cubic foot. It has been a cheap building stone, 5 or 6 blocks costing 3 to 4 annas in 1943 when labour was cheap. The then price for 100 slabs ranged between Rs. 5/- and Rs. 10/- depending upon the size and workmanship. About half a dozen blocks can be cut by one man in one day. Solid and loose varieties of laterite have also been used by village smelters for manufacturing iron.

Lime

Calcareous concretions (*ghootin* or *kankar*) are obtained in the alluvium over much of the district but no bedded limestone has so far

been found. The local lime requirements for building purposes are mainly met by burning either this *ghootin* or the sea-shells in the coastal tracts.

On the northern side of Jatia hill (85° 12′ : 19° 41′), in the cultivated ground there are some small abandoned quarries from which *ghootin (kankar)* has been extracted in the past. A bed of *kankar,* reported to be about 4 feet thick but of which only about 2 feet are exposed, occurs below 3 feet or more of black cotton soil. The *ghootin* bed rests on decomposed gneiss. A similar deposit is found over an area of several acres on the southern side of the hill near the shore of the lake, where the bed of *ghootin* is about 3 feet thick and capped by 3 to 4 feet of soil. These beds of *ghootin* consist of a loose mixture of about 70 per cent of lime of good quality with 30 per cent of earthy matter. Along the banks of Chilka lake many similar patches of *ghootin* exist, each occupying a few acres. The total quantity of *ghootin* to be expected from such deposits could not support a large cement or lime factory, but it can cater for local requirement for years to come. An idea of the low cost of quarrying and burning the material may be had from the rates that prevailed before the present day increase in the cost of living. The rates quoted hereafter were obtained during the period 1941-43. Labour was paid at the rate of 9 pies per cubic foot for the *ghootin* picked from the surface and As. -/1/- to As. -/1/3 per cubic foot for the excavated material. Royalty charged by the Forest Department was Rs. 2/- per 100 cubic feet of *ghootin* extracted, but it was much lower for the material from private land. A lime kiln at Balugaon (85° 12′ : 19° 45′) utilized these deposits using coal as fuel, the first firing being done by wood. The kiln consisted of an open rectangular structure of mud and bricks divided into three compartments each with a capacity of about 300 cubic feet. The two or three labourers employed were paid at the rate of Re. 1/- per 100 cubic feet of burnt lime, their average income coming to four annas per day per head. The lime was sold for Rs. 22 to Rs. 25 per 100 cubic feet.

Ghootin is found in the sub-soil at various other places further inland in these regions, *e.g.*, Champagarh Protected Forest and Rajin Reserve Forest, but the proportion of concretions in the soil is not high and the quality of material obtained is poor, including much clayey matter.

SAMBALPUR

(B. C. Roy)

Building stones

Some of the fine and medium-grained pink or grey gneisses in the district are suitable for dressing as building materials. The coarse porphyritic granites near Lukopali (20° 46′ : 82° 33′) in the neighbourhood of Nawapara town could be used for decorative purposes.

Some impure marble bands (calc-gneisses) occur around Mahuabhata (20° 32′ : 82° 44′), Bhalubahal (20° 26′ : 82° 44′) and other localities. In the former locality the calc-gneisses are associated with garnetiferous gneisses. Along the Bhalubahal *nàla,* just east of the Kumna-Khariar road, flaggy intercalations of light greenish calc-silicate rocks and quartzites occur in coarse porphyritic granite.

A micaceous quartzite of bluish grey colour in the ridges just east of Sambalpur town is extensively employed in the town.

The district abounds in quartz-schists and quartz-mica-schists suitable for flooring and roofing purposes. One exposure of quartz-sillimanite-schist at Dudkabahal (21° 57′ : 84° 15′) is quarried for building purposes. The usual dimensions of the dressed slabs are: 3 ft. × 1½ ft. × 2 in., 2 ft. × 1 ft. × 1 in., 2 ft. × 1 ft × ½ in., 1½ ft. × 9 ins. × 1 in., and 1½ ft. × 9 ins. × ½ in.

Certain slates, usually black and sometimes red, apparently obtained locally from the bed of the Mahanadi, are used for flooring and roofing in Sambalpur town.

The small ridges about one mile south-west of Khantamal (21° 55′ : 84° 17′) consist of angular fragments of epidote and quartz cemented by a network of secondary quartz of variegated colour, which may be worked for decorative purposes. The silicified fault breccia near Putka (21° 10′ : 82° 58′), containing a network of chalcedony, flint, jasper and bloodstone, is also suitable for ornamental purposes.

The Cuddapah sandstones, quartzitic sandstones and flagstones in the Bargarh and Nawapara subdivisions hold considerable reserve of building materials. The flagstones around Gemjor (20° 31′ : 82° 36′), Khadupani (20° 13′ : 82° 32′), Jobbhata (20° 10′ : 82° 31′) and Pandripani (20° 11′ : 82° 32′), and numerous other localities, may be employed for roofing or flooring.

Some of the fine-grained Gondwana sandstones around Ib, B. N. Railway, are quarried for dressing as building stones. One quarry is located about half a mile west of Telenpali (21° 49′ : 85° 56′), on a small sandstone hillock. The material is employed for the construction of the new town of Ib where a paper mill has been recently constructed. The railway bridges around Jharsuguda and Sambalpur are reported to have been built of Gondwana sandstones. Some of the thin red flagstones around Liakhai (21° 51′ : 83° 50′) and Ulap (21° 51′ : 83° 49′) should also furnish material suitable for flooring.

*Talc- and chlorite-schists that occur in association with quartz-schists and quartzites in Sambalpur area can be easily split and cut into thin slabs for roofing and flooring. Some of the outcrops near Kardola (21° 10′ : 84° 54′) and Chhiplima (21° 21′ : 83° 54′) along the bank of the Mahanadi and near Kulia (21° 30′ : 84° 04′) and Kutrajori (21° 28′ : 84° 05′) in the Malti basin contain good material which is locally raised for supply to Sambalpur and the neighbouring villages.

Laterite

The patches of lateritic gravel or *murram*, so common in the district, are quarried for domestic stone materials and road metal.

Lime

The Cuddapah limestone of Bargarh and Nawapara should be suitable for lime burning or cement manufacture. About a mile and a half

* Recorded by Dr. A. G. Jhingran, Geologist, Geological Survey of India.

south-west of Silhatpani (20° 36′ : 82° 35′), in the Makerchua hills, small deposits of travertine occur on outcrops of quartzite. The lime is usually concretionary in apprearance and sometimes shows shaly and cherty inclusions and has presumably been derived from calcareous shales, cherty and porcellanic rocks, which occur in association with the quartzites in the more elevated regions of the Makerchua hills on the Khariar plateau. The deposits are of minor importance and suitable only for local lime burning.

Superficial *kankar,* locally known as *asur-har,* occurs widespread as concretionary matter in the alluvium, covering rocks of widely different composition. It is employed for local lime-making.

Ballast

The dolerites and epidiorites in the granite gneisses are quarried for the construction of local roads. Some of the quartz veins cropping out around Jharsuguda, B. N. Railway, are utilized for railway ballast. The exposures of massive quartzite, south of the Rengali railway station, are also worked for similar purposes. The quartzitic pebbles in the conglomeratic sandstone hillocks around Ib, B. N. Railway have been extensively employed in the past for railway ballast.

CHAPTER XI

CLAYS

General

The utilization of local clays by village potters is widespread throughout Orissa as in other parts of India, but there has been no great development of the clay industry on modern lines such as in Bihar and in Bengal. The reason for this is twofold: there are very few known deposits of first class clays in Orissa and fuel is comparatively high in price. In Sambalpur district refractory clays are mined and railed to Jamshedpur for the manufacture of firebricks. In Jeypore a recent venture on modern lines has been successful in the manufacture of high class tiles, using local clays. A certain amount of clay is mined in the coastal area for use in the textile industry at Berhampur. Numerous small deposits are worked by local villagers for use as whitewash.

Uses and Classification

Clays are essential for many purposes, but the principal uses in India are in the manufacture of village pottery, building bricks, cements, firebricks and other refractory articles, ceramic ware and as a filler in the paper and textile industries. Other minor uses to which clays are put in India are in the manufacture of soap, for medicinal purposes, caste marks, colour washing, and modelling of Hindu images.

Potter's clay—The village potter uses suitable earths adjacent to his village, for the manufacture of roofing tiles, domestic utensils and local brickmaking. These earths are either the decomposition products of rock *in situ* or are sediments deposited along river valleys and are very

impure. They naturally vary enormously in quality from place to place, giving rise to fired products of different colour, porosity and strength; the pottery manufactured in certain localities acquires a reputation for particular purposes owing to some peculiarity in property. In view of the widespread distribution of potter's clays, any survey of them throughout the province would be a special undertaking.

Brick clays—Clays suitable for brickmaking may be very impure; they are widely distributed and are obtained as surface earths and from the recent alluvium of the deltas or along the river valleys. It is possible to manufacture bricks almost anywhere in the province, from clays adjacent to building sites. Such bricks vary widely in quality, but usually the standard required in this part of India is not high. On the whole, the greater the plasticity of the clay the better is the quality of the brick. The poorness of many bricks used in the province is a consequence of the very sandy nature of many of the clays used. In view of the widespread nature of this material, brickmaking clays need not be discussed further.

High quality clays—Clays of better quality, necessary for the firebrick, ceramic, paper and textile industries, may be divided into two varieties from the industrial point of view: (*a*) refractory clays, used for the manufacture of firebricks and other refractory articles and (*b*) clays used in the ceramic and other industries. Such clays are of three types —sedimentary clays, kaolins or clays derived from the decomposition of felspar *in situ,* and lithomarges or clays which are found immediately underlying laterite.

The best quality clays, which can be used for the manufacture of high grade white ceramic goods, or are white in colour and can be used in paper and textile industries, are known as china-clays. The majority of such clays are kaolins, but it by no means follows that all kaolins can be used for this purpose, as staining destroys the value of many. All true kaolins are highly refractory, but only the poorest qualities are used for making refractory materials. Certain sedimentary clays are sufficiently pure and white in colour to be used as china-clays. The prices which china-clays command, particularly those of good quality, are far higher than for other clays.

Distribution

The majority of the known clay deposits of Orissa are in Sambalpur district, where both sedimentary clays and kaolins occur. Of the sedimentary clays, fireclays occur in the Gondwanas at Jorabaga, Darlipali, Rampur, Bundia, Katabaga, Kodopali, Ainlapali, Krarama Balput and Chualiberna. A white clay which might be used as a china-clay also occurs in the Gondwanas at Baripahar, whilst similar white clays occur in the Cuddapahs at Khola and Lukapali. China-clays of the kaolin type occur at Ghichamura, Sagnupali, Chuhukitikra, Banjipali, Piplipali and Katapali, and have been reported from Dessar and Paharsigira. Lithomarge has been found at Akhradand.

In Koraput no fireclays have been found, but there are several known deposits of china-clay of the kaolin type. These occur at Deodra, Boipariguda, Oduguda, Musoriguda, Pukkili, Jodiguda, Nuagam and Ambodala. In addition, certain alluvial clays near Jeypore are used

at the Jeypore tile factory for the manufacture of roofing and flooring tiles, drain pipes, polished bricks and other articles.

In Ganjam, small deposits of the kaolin type are found at Gundaranga, Dwaragam, Polosara and Buguda.

In Puri district, the clays are of the sedimentary type in the Gondwanas, similar to those in Sambalpur and have been mined in the Barhapita Reserved Forest, and at Bharathpur and Jagannathprasad.

In Cuttack, clays of the Gondwanas are known to occur at Naraj and at Brahmanbil and Patrapara in Angul subdivision.

So far as the Gondwana clays are concerned very large amounts indeed are available, as the beds are invariably persistent both in strike and dip. Mining, however, will be limited more or less to their outcrops, for in depth overburden either of soil or sandstone increases rapidly and by open quarrying the economic limit is soon reached. Their dip is invariably shallow, so that either a large amount of clay would have to be left in pillars or expensive timbering undertaken.

The quality of the Gondwana clays, although suitable for refractories and stoneware, is not up to that required for the better type of ceramic ware, such as white pottery and porcelains.

The china-clays of Sambalpur and Koraput are of fair quality. The deposits examined in Ganjam are all small and material of poor quality, although this would be improved by washing. It is not possible without extensive prospecting to determine the quantities available in each deposit, nor is such prospecting essential. Several of the deposits described here, except those in Ganjam, appear to be sufficiently good to warrant development and, in the majority of cases, each will be found to occur over a rather larger area than that visible at present. Some of the clays are of a quality suitable for the manufacture of white pottery and other ceramic wares and others for filler in the textile and paper industries. Considerable research might be undertaken on these clays from the point of view of their use and the mixing of clays from different sources.

CUTTACK

(A. K. Dey)

Pottery clays

Potter's clay is quite widely distributed in Cuttack. Perhaps the best known occurrence is on the left bank of the Mahanadi at Kakhadi, near Cuttack.

Kakhadi (20° 30′ : 85° 46′): A 3-foot bed of dark plastic alluvial clay is exposed along the bank of the Mahanadi close to this village. It rests on a sandy bed and is overlain by a soil mantle measuring up to 15 feet in thickness. The clay is excavated by the village potters from places where the soil covering is thin or has been removed by the river. It is used in making village utensils.

**Kendupali* (20° 19′ : 85° 22′): About ¾-mile N.W. of the village. in the area between the two lakes, a deposit of dark-grey, non-gritty,

* Recorded by Mr. G. C. Chaterji, Geologist, Geological Survey of India.

plastic clay is found over a large area under a thin mantle of sandy clay. On sun-baking the material becomes quite tough and can be used for the manufacture of earthen ware such as cooking pots, pitchers, pipes, tiles etc. It is used locally for plastering the floors of the village huts.

China-clay

White clay is commonly found associated with the Gondwana sandstones and shales in Cuttack.

Naraj (20° 28′ : 85° 46′): This village is about nine miles from Barang Railway Station and thirteen to fourteen miles from Cuttack via the Mahanadi. Beds of white clay occur in the Gondwana sandstones and are well exposed along the bank of the Mahanadi for a distance of about 2½ furlongs upstream from the Inspection Bungalow. The beds range in thickness from one to seven feet and have an overburden of twelve to twentyeight feet of sandstones and shales. Dips are low, not exceeding 7° southwards. Commonly thin bands of red ochre, 1 to 3½ inches in thickness, intervene between the clay and the sandstone. At one place along the bank, the following sequence from the top is seen:—

Sandstones	15 ft.
White clay with rare stains of iron	7 ft.
Sandstones	5 ft.
White clay	—

A little upstream, another section shows from the top 23 feet of sandstone, 2½ inches of red ochre and 3 feet 3 inches of fine white clay containing streaks of iron stains.

Generally the Naraj clay is white with stains of iron here and there. It is fine to moderately gritty and is extracted by the local villagers for whitewashing purposes. It is also sold at Cuttack as a substitute for chalk.

A test made on a sample of clay from Naraj gave the following results:

Colour before firing, grey; colour after firing, white; plasticity, poor (gritty); fusibility—does not fuse; shrinkage (linear), nil. The fired brick is wanting in coherence and breaks up on application of slight pressure.

Another sample from the same locality yielded the following results:

Colour before firing, grey; colour after firing, drab grey; plasticity, fair; fusibility—does not fuse; shrinkage (linear), nil. Colour becomes darker on firing.

On the north-east side of Sideshar hill, about a mile south-west of Naraj, a compact cream-coloured clay is exposed below yellow ochre which occurs under laterite. The clay overlies some carbonaceous shales. The exposure is small and the extent of the deposit could not be determined. Further west, to the north of the Sideshar temple, a similar

clay bed is exposed in a quarry on basaltic rock along the bank of the Mahanadi, showing the following section:—

Laterite	...	...	...	...	—
Brownish red ochre	..	...		..	+3 inches.
Clay bed	..	...	.	...	5 ft.
Decomposed basalt			...	...	7 ft.
Basalt	..	...	...	...	—

The clay has become somewhat hardened and splintery as a result of the intrusion of basaltic rock.

The cream-coloured clay from the north-east side of Sideshar hill is plastic and free from grit. When tested it showed:

Colour before firing, grey; colour after firing, slate-grey; plasticity, high; fusibility—does not fuse; shrinkage (linear), 10 per cent. Colour becomes darker on firing and the fired brick is very coherent.

**Baideswar* (20° 21′ : 85° 25′): At the foot of the Baideswar hill, in a *nala* west of the Inspection Bungalow, dirty yellow, gritty kaolin mixed with soil material occurs on the weathered surface of the gneissic country rock. Small quantities of the material are used for colour washing of the village huts.

Brahmanbil (21° 03′ : 84° 56′), Angul: A sample of clay collected from the bank of a *nala* about one mile N.N.W. of this village was found on testing to be plastic but gritty and fusible.

Patrapara (21° 05′ : 84° 46′), Angul: Beds of grey fireclay ranging from 4 inches to 6 feet 7 inches in thickness occur with the coal seams exposed along the Madalia stream for a distance of about 6 furlongs, west of Patrapara. The material is usually hard, fine and plastic. When heated to about 1,400° C, it shows a linear shrinkage of about 10 per cent but does not fuse or crack. Its colour after firing is greenish-brown.

†*Banrpal* (20° 50′ : 85° 13′), Angul: Poor quality, gritty china-clay, resulting from the kaolinisation of coarse granite-gneiss, occurs along the *nala* banks about half a mile to the south-west of the village.

†*Raijharan* (20° 57′ : 84° 59′), Angul: Two small deposits of china-clay occur near the Raijharan Forest shed. The clay has resulted from the partial kaolinisation of small thickness of Mahadeva sandstones and is of academic interest.

†*Chendipada* (21° 05′ : 84° 52′), Angul: Three small deposits of white clay occur in partially altered Mahadeva sandstones in the Kurumani, Gowdari and Gurkha *nalas* respectively, close to the village. The clay is used locally for whitewashing village huts.

* Recorded by Mr. G. C. Chaterji.

† Recorded by Mr. S. Krishnaswamy, Geologist, Geological Survey of India.

**Tentloi* (21° 02′ : 84° 52′), Angul: Two very small exposures of slightly kaolinised Mahadeva sandstones occur along the banks of a small *nala* adjoining the Chendipada-Tentloi cart tract, about 3½ miles south of Chendipada Inspection Bungalow.

**Machhakata* (21° 04′ : 84° 50′), Angul: A number of detached exposures of partially kaolinised Mahadeva sandstones are present along the banks of the Kusai (Barjora) *nala* and its tributaries between the villages Ghuntiliposi (21° 04′ : 84° 50′) and Sapuinali (21° 05′ : 84° 49′). The deposits are not large and the quality of the clay is poor, being gritty.

**Purunagarh* (21° 06′ : 84° 50′), Angul: On the left bank of the Kusai (Barjora) *nala*, about two furlongs south of the village, kaolinised Mahadeva sandstones are present over a very restricted area.

Lithomarge

†Yellowish-white lithomarge occurs under a capping of laterite north of Bandgaon (20° 59′ : 85° 54′), Koilaw (21° 02′ : 85° 53′) and Sapuapada (20° 59′ : 85° 56′). The material is used locally as a colourwash.

GANJAM

(G. C. Chaterji)

Several white clay deposits occur in various parts of the district. Most of these are of superficial kaolin on the decomposed surface of granitic gneiss along stream courses. In some cases the deposits proved to be the decomposition product of pegmatites. White lithomarge is sometimes associated with laterite. The deposits so far found are all small and the clay requires careful washing to remove grit. It is not at all improbable that during further mapping in this district further deposits will be found.

Gundaranga (20° 14′ : 84° 08′): South of this village near Sorongodo (20° 14′ : 84° 07′) in Balliguda subdivision, there is a superficial deposit of gritty kaolin along the bed of a stream, as the product of decomposition of a felspathic granitic gneiss. The deposit extends as a strip for about two furlongs along the course of the stream. It is capped by a red earthy soil, from 8 to 15 feet in thickness. A thickness of about 3 to 4 feet of the kaolin-bearing zone is exposed above the stream level. The kaolin is very gritty with associated fine quartz and decomposed garnet; it is badly iron-strained near the surface. After excavating to a depth of 2 or 3 feet the quality did not improve, although a slight improvement of colour was noticed. Outcrops of solid granitic gneiss occur close by.

Laboratory tests on samples of the clay yielded the following results:—

Fairly soft; gritty; plasticity moderate; colour (unburnt) light yellow, colour (burnt) white; linear shrinkage about 10 per cent; neither warps nor fuses but cracks a little at about 1,400° C.

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* Recorded by S. Krishnaswamy.

† Recorded by Mr. G. P. Rath, formerly Assistant Geologist, Geological Survey of India.

The grit can be removed by washing and the plasticity improved.

The material is locally used for whitewashing. The area over which the deposit occurs is very limited; and the quality in the crude state is poor.

Siringia (20° 10′ : 84° 09′): To the east of this village, on Talisoru hill, some small patches of white lithomargic material are associated with laterite over gneissic rock. The lithomarge is found in stray lumps here and there. No workable deposit occurs.

Dwaragam (19° 20′ : 84° 32′): A small deposit of sticky clay occurs in the bed of a *nala* running over porphyroblastic granitic gneiss rich in felspar near this village in Berhampur subdivision. The deposit covers a very small area with an average thickness of 3 to 4 feet. The material is badly iron-stained and gritty, and contains much calcareous and other impurities. It has no commercial value.

Polosara (19° 41′ : 84° 49′): About two miles north-east of this village, between villages Jillunda (19° 42′ : 84° 51′), and Santarapalli (19° 43′ : 84° 51′) in Chatrapur subdivision, small patches of gritty kaolin occur at the foot of hills. The country rock is a coarse-grained granitic gneiss rich in felspar with some small dyke-like bands of basic granulites, and the kaolin is due to weathering of the gneiss along the *nalas* and under alluvial cover. One of these deposits, about half a mile E. S. E. of Santarapalli, occurs under a thin soil cover about 2 or 3 feet in thickness where it has been excavated by the local villagers. The excavation has reached a depth of about 6 or 7 feet from the surface, the deposit continues deeper but the width and the lateral extent of the kaolin is small and the excavation is surrounded by solid country rock on all sides. The material is slightly gritty and has a greyish white colour; but the greyishness disappears on powdering and sun-drying, while grittiness is removed by washing.

Briquettes on firing to a temperature of about 1,400° C become yellowish-grey in colour and the surface becomes spotted, but it neither cracks nor fuses. Linear shrinkage is about 12·5 per cent.

The deposit has been exploited on a small scale by the local villagers who sell the clay to neighbouring villages for house decoration purposes. The very limited lateral extent of the deposit would not allow its exploitation on a large scale.

Buguda (19° 47′ : 84° 47′): Near this village and south of village Satanala or Satrusola (19° 47′ : 84° 49′) in Ghumsar subdivision, patches of kaolin are found associated with decomposed gneiss and accompanying pegmatite veins along the Kalobhuti *nala*. Along both sides of the *nala* the surface is covered with a varying thickness of alluvium and boulder bed, which reaches a maximum depth of about 18 feet. At one point a layer of gritty kaolin only about one foot thick occurs between two zones of decomposed granitic gneiss. The deposit shows no tendency to increase in thickness with depth. It appears to be the decomposed product of a felspar-rich zone in the granitic gneiss. At another point nearby occurs another patch of a highly plastic kaolin which is coloured brownish near the surface. Excavation to a depth of five feet did not show any improvement in colour, on the contrary it became greyish-green with brown patches. The kaolin is very fine-grained but

there are large pieces of quartz and garnet associated. On being tested in the laboratory it was found to be highly calcareous and consequently of no industrial value. Other similar irregular patches are found here and there in the vicinity.

KORAPUT

(A. M. N. Ghosh and A. K. Dey)

Pottery clays

These can be divided, according to their mode of origin, into (*a*) transported or alluvial clay deposited by rivers, and (*b*) residual clay formed as a result of weathering and decomposition of basic rocks such as charnockite, norite, etc.

Alluvial clay, such as is found in the immediate neighbourhood of Jeypore, is both brown and black in colour and sufficiently plastic for making country tiles, water vessels, cooking utensils and other domestic articles. There is no difference in character between the brown and the black clay, the colour of the latter being due to the presence of humus and other organic matter. Both black and brown clays occur immediately to the south-west of Demsaguda (18° 51′ : 82° 35′) and again on the northern bank of the Dudhi Jholla, a little over half a mile south-west of the former village. This type of clay is used by the local potters and there will be no dearth for many years ; it is practically inexhaustible.

This clay is also used in the Jeypore tile factory for making roofing and flooring tiles, drain pipes, polished bricks, flower pots and vases and *terra cotta*. For this purpose it is mixed in the ratio of 2 : 1 with a variety of highly plastic and sticky, mottled yellow and cream-coloured clay, which is found in the stream sections north-east of Bodosal (18° 52′ : 82° 35′), about a mile and a half E.N.E. of Jeypore. The latter variety is a residual deposit, formed by the decomposition of the underlying rocks *in situ*. This is evident from the traces of faint gneissic structure preserved at one place on the western face of the clay pit. The clay passes imperceptibly into the overburden of the soil cap, which at the pit is 2 to 5 feet thick. It has presumably been formed by the weathering of charnockite, which crops out nearby. At present the face of the clay band, as exposed on the west bank of the stream, is 80 feet long, and the deposit here will have rather a limited life depending on the quantity removed from time to time. There is, however, a possibility of the extension of the clay in a westerly direction under the ploughed fields. It is, therefore, recommended to sink a few trial pits and borings to depths say 25 to 30 feet at intervals of 50 to 100 feet, in order to determine its extent both laterally and vertically.

Another type of residual clay, characterised by a reddish and maroon colour due to richness in ferric oxide, is added to the mixture of the brown and yellow clays in the Jeypore tile works. At present the red clay is obtained from a place on the main road to Koraput at the northern end of the Nokti Dongar hill, intermittently around its base for nearly half a mile. The clay is gravelly in places, but the gravel can be removed by washing or sieving. There will be no dearth of this clay, which also occurs on the plateau near Koraput and again on the road to Gunnyyapada.

China-clay

Deodra (19° 18′ : 82° 27′): An occurrence of cream-coloured clay was noticed in some jungle, about 1 to 1½ miles W.N.W. of the village of Deodra, a little over 12 miles W.N.W. of Nowrangpur. The clay is excavated by the neighbouring villagers and is reported to be used for whitewashing their houses as a substitute for lime. The area over which it is dug is 30 feet by 30 feet and the pit is nearly 10 feet deep. The clay at the top is contaminated with soil cap which is 3 to 4 feet thick. It occurs on the dip slope of purplish and reddish shales and quartzite, but the plane of junction is hidden under the soil cap. A few trial pits are needed, therefore, to determine the relationship of the clay and the underlying rocks and also the lateral and vertical extent of the clay band.

Physical tests carried out in the Geological Survey of India laboratory show that the clay has very good plasticity and can be used as fireclay. The clay is soft and soapy to the feel. The colour, when unburnt, is cream-white and nearly the same when burnt; it neither cracks nor fuses at about 1,400° C; linear shrinkage is about 7·5 per cent.

If a large deposit is proved by excavations or borings, cost of mining and transport should be low. The overburden of soil is comparatively thin and can easily be removed. The cost of transport to Nowrangpur in 1940-41 was about Re. 1-8-0 to Rs. 2 per cart, carrying up to 15 maunds.

Boipariguda (18° 45′ : 82° 26′): Mottled cream and yellow clays occur in large quantities in the low-lying lands within a mile north-east of Boipariguda. The clays have resulted from the decomposition of gneissic rocks. Pockets of yellow ochre are also found (*see* under Mineral Pigments).

Oduguda (18° 48′ : 82° 45′): It appears that the 3,000-foot Koraput plateau contains scattered deposits of kaolin, which occur almost side by side with laterite. One such kaolin deposit was examined about 2½ miles E.S.E. of Koraput; it occurs in the bed of a stream about three furlongs south-east of Oduguda and a little over half a mile N.N.E. of milestone 48 on the motor road. Although the deposit seems extensive the material examined cannot be regarded as high class, as it is sandy and stained by oxides of iron. Locally, however, the quality improves, resulting in a somewhat purer grade of kaolin. The quality could be further improved by washing and sun-bleaching.

The stream along which the clay occurs is well below the laterite level and the deposit is covered by a fairly good thickness of alluvium. The topography—a flat shelf of hillwash and alluvium banked against and surrounded by laterite hills with occasional boulders of charnockite, etc., in the side stream—suggests that the river has carved its passage along the softer zone of kaolin, which is likely to extend on both sides of the river at least about 150 feet to the base of the hills. The clay has been formed by the alteration of gneissic rocks *in situ*. There may be a difference of opinion whether this alteration has been caused by surface weathering or by deep-seated solutions and gases. The following evidence is advanced in support of the latter view:—

(1) The kaolin carries narrow veins of quartz and pegmatite.

(2) At one place on the bank of a side stream, granite was noticed with phenocrysts of kaolinised felspar.

(3) Presence of greisenised rocks.

(4) Kaolinisation is restricted to certain zones within limited areas. It is not co-extensive with the laterite over the plateau.

(5) The kaolin occurs as bands in decomposed and possibly undecomposed rocks.

The mode of origin has a direct bearing on the quality and quantity of the kaolin. If brought about by carbon dioxide and other volatiles given off during the later stages of magmatic activity, the chances of its persisting at depth and improving in quality are far greater than they would be if due to weathering. The stains of iron oxide in the kaolin are probably superficial and may disappear at depth.

The deposit continues about 500 to 600 feet along the bed of the river, its average thickness, as exposed above the river-bed, is about 3 feet and it has an overburden of hillwash and alluvial soil 25 to 30 feet thick. At one place about 15 feet of kaolin was exposed on the western bank of the river. It is close to a motor road. The difficulties to be faced in working the deposit will consist in the removal of the thick overburden of loose soil. Further, most of the work will have to be done at about water level and the sudden flooding to which such hill-streams are prone during the rainy season may seriously interfere with the operations. These difficulties can be partly overcome by the construction of a dam some distance upstream, and overburden removed by hydraulic jets thus exposing the surface of the kaolin. The occurrence of the deposit on the bank of the river will permit the material to be washed downstream, to get rid of such impurities as mica, graphite flakes, quartz grains, sand, grit, etc., and the slush finally lead into vats to obtain the better grades of kaolin.

Tests made in the Geological Survey of India laboratory yielded the following results:—

Average sample from river bank, Oduguda: Clay, mixed with very little graphite; soft, slightly gritty; plasticity very good; colour (unburnt) pinkish-white; colour (burnt) dirty yellow; linear shrinkage about 15 per cent; neither cracks nor fuses at about 1,400° C.

Sample from northernmost point at river, Oduguda: Clay, mixed with little graphite; soft, fine; plasticity very good; colour (unburnt) creamy white; colour (burnt) black; linear shrinkage about 15 per cent; neither cracks nor fuses at about 1,400° C.

Another sample of clay, mixed with a little graphite; soft, somewhat gritty; plasticity very good; colour (unburnt) pinkish-white; colour (burnt) dirty white, with slight black coating; linear shrinkage about 10 per cent; neither cracks nor fuses at about 1,400° C.

These tests indicate that the clay cannot be utilised for the manufacture of high class porcelain ware, but its refractory nature makes it suitable for the manufacture of inferior types of ceramic ware such as stoneware, drain pipes, etc. It could also be used as a filler in textiles, and in paper manufacture.

Two bands of good kaolin, striking north-south, were noticed in kaolinised gneiss along a *nala* about a furlong north of milestone 49 on the motor road and little over a mile to the south-east of Koraputi. Owing to the overburden of loose lateritic soil the thickness of the bands could not be determined. Kaolinised gneisses were also noticed in a stream section west of milestone 49/1. Here the kaolinised gneisses support an overburden of hillwash some 20 feet thick. The exposed portion of the kaolin is 3 to 40 feet thick but the material is very gritty and impure.

Musoriguda (18° 52′ : 82° 41′): About four miles N.N.W. of Koraput, kaolinised gneisses occur along the east bank at the junction of two streams, just north of the village Musoriguda. Although kaolinisation has been extensive, the purer material occurs only as thin veinlets up to 4 inches in thickness. The quality does not appear to be good, as the kaolin is mixed with much sandy material. Kaolinised gneisses are exposed at several places in the neighbourhood. They support an overburden of iron-stained clayey soil varying from 5 to 10 feet in thickness. Most of the kaolin occurs near the water level, which would make mining difficult. Preliminary physical tests of the kaolin were made in the Geological Survey of India laboratory and gave the following results:—

Soft, fine; plasticity very good; colour (unburnt) cream-white; colour (burnt) greyish buff; linear shrinkage about 15 per cent; neither cracks nor fuses at about 1,400° C.

Pukkili (18° 30′ : 82° 54′): White clay near the base of a hill at Nelakondavalasa, near Pukkili, has been formed by the decomposition of the underlying gneisses. The surface exposure of the clay is not large. The material is somewhat gritty but contains here and there patches of fine clay. Its plasticity is good and it does not fuse when heated to 1,400° C, but develops a slight warp; linear shrinkage about 30 per cent. The deposit is finely banded in places with layers of ferruginous matter.

About a mile N.N.W. of Pukkili some white gritty clay is exposed along the left bank of a *nala,* a little above its junction with the Kolab. The material is of poor quality and is locally used as colour-wash.

Jodiguda (18° 20′ : 82° 46′): Some pinkish clay, mottled yellow and white, and probably of lateritic origin, is developed over an area of 300 feet by 200 feet, on a low hill west of Jodiguda. The material is plastic and shows a linear shrinkage of about 35 per cent; on firing at 1,400° C it does not fuse but develops a very slight warping. The colour on firing is dark grey.

Nuagam (19° 06′ : 82° 30′): White clay resulting from the decomposition of gneisses is sometimes found in well sections. A sample of such clay from a well at Nuagam was tested. It is soft, very gritty, with a poor plasticity. When heated to 1,400° C, it became slightly vitreous but did not crack; linear shrinkage about 7·5 per cent. Its colour after heating was greyish-white.

Ambodala (19° 49′ : 83° 28′): Some white clay resulting from the decomposition of gneisses is exposed along the right bank of a stream about three-quarters of a mile S.S.W. of Ambodala railway station. The material is gritty, plastic, and does not fuse or crack when heated

to about 1,400° C; linear shrinkage 7·5 per cent: the colour becomes dirty brown with dark spots. It is locally used as colour-wash.

Similar small deposits were seen E.N.E. of Madhupur (19° 53' : 83° 28') and north-west of Ladipanga (19° 40'; 83° 30').

Pittakonda (18° 11' : 81° 56'): Along the left bank of a *nala* about three-fourths of a mile E.N.E. of the village, greyish-white clay has resulted from the decomposition of granitic rock. The deposit is small and the material is of poor quality, being gritty and iron-stained.

Singarajukunta (18° 17' : 81° 48'): A very small deposit of gritty and slightly iron-stained clay occurs on the left bank of a *nala*, about two miles south of the village. The deposit has been formed by the alteration of granitic rock and can only be used by local villagers for whitewashing.

Puri

(G. C. Chaterji)

In Puri district the deposits of clay which have been examined are all within Khurda subdivision. They occur as sedimentary beds associated with the Gondwana rocks which crop out south of the Mahanadi. These beds have already been worked on a small scale at a few places, and are associated occasionally with ochre. The beds are rather flat-lying with slight dips here and there, and individually extend over several acres with a thickness of anything between one and four feet or more. These clays are used locally for whitewashing and are despatched to Berhampur (Ganjam) foi use as a textile filler.

Barhapita Reserved Forest: In Barhapita Reserved Forest a clay deposit occurs on a hill called Khari Munda, east of Barthali Mundia (20° 20' : 85° 51') about 3 miles north-west of Kantabar (20° 19' : 85° 43'). The section at the existing quarry shows red soil at the surface followed by 12 feet of sandstone overlying a white clay bed reported to be about 3 to 4 feet thick. The workings, now abandoned, persist for about 50 yards along the strike, but at present the clay bed is exposed at only one spot, elsewhere the bed is covered with quarry debris. In this one excavation the bed dips south at a very shallow angle, up to 5°; only about 2 feet of the clay is now exposed, the upper 12 inches of which is massive the lower half being shaly. The bed is probably continuous over a considerable area, but such as thin bed is unlikely to crop out or be apparent in this sandstone area. Its lateral extension may be determined by trenching.

The clay is greyish-white to white in colour, with rare red ferruginous stains along the bedding planes. A test made on a sample of this clay in the Geological Survey of India laboratory yielded the follow ing results:—

Soft; fine to sandy; plasticity good; colour (unburnt) white; colour (burnt) light grey; linear shrinkage about 7·5 per cent; neither cracks nor fuses at about 1,400° C; brick rather friable.

It could be used either as a refractory clay or possibly mixed with other clays for the manufacture of stoneware. It was worked inter-

mittently for many years, up to only a year or so ago. It had been used for whitewashing huts and some had been exported. Transport facilities are good. Cost of transport by bullock cart was about Rs. 2-8-0 per ton to Bhubaneswar railway station in 1940-41. From the mining point of view, the thick overburden of sandstone will preclude its being worked economically to any depth into the hill. Future work will be along the strike outcrop as the bed is obviously persistent. Cost of removing overlying debris to get at the outcrop along the strike would add greatly to the cost of working.

Bharathpur (20° 18′ : 85° 47′): Just south-west of mile 9, on the Chandka-Khurda road and about three quarters of a mile west of Bharathpur in the Andharwa Undemarcated Forest, there is an outcrop of white clay. The seam here is more or less horizontal, the maximum dip being 2° to 3° to the S.S.E. A section in an excavation showed 8 feet of red soil capping, then a thin sandstone bed followed by about 1 foot 6 inches to 2 feet of thick white clay overlying a white sandstone, of which about 6 feet to 8 feet is exposed. The clay bed is obviously persistent over a considerable area.

The laboratory tests gave the following results:—

Soft; fine; plasticity good; colour (unburnt) white; colour (burnt) white with yellowish tinge; linear shrinkage about 12·5 per cent; neither cracks nor fuses at about 1,400° C; brick is friable.

This clay also might be used for refractory purposes or possibly mixed with other clays for stoneware.

The deposit has been worked by contractors on lease from the Forest Department, and the material is exported mainly to Berhampur where it is used by the weavers as a cloth filler. The associated white sandstone is also excavated and shaped into tiles for local use.

Jagannathprasad (20° 20′ : 85° 46′): In the Jagannathprasad Reserve Forest to the east of the Chandka-Khurda road, close to mile 12 and north-east of village Jagannathprasad, clay has been extracted from many small pits. The clay occurs below an 8 foot overburden of soil and sandstone; the full thickness of the clay is not exposed, but it is at least 4 feet. The upper 18 inches is red in colour, the remainder is grey or pinkish-grey with pockets of white soft material. The grey and red clays are rather hard The deposit is practically flat-lying with slight undulations here and there, and is quite extensive. Apparently the clay is obtained wherever the overburden is removed over an area of several acres.

The average result of laboratory tests on this clay is as follows:—

Soft; fine to sandy; plasticity good; colour (unburnt) white to greyish-white; colour (burnt) yellowish-white to yellow; linear shrinkage 5 to 7·5 per cent; neither cracks nor fuses at about 1,400° C; brick is friable.

Like the previous clay it might be used for refractory purposes, or mixed with other clays for stoneware.

The deposit is worked on a small scale by the local villagers, under contract from the Forest Department, and the material is despatched

to Berhampur where it is used as a cloth filler. Transport facilities are good. Cartage to Bhubaneswar railway station, about 10 miles away, cost about Re. 1-8-0 to Rs. 2 per ton in 1941.

Lithomarge

**Patharkatha* (19° 48′ : 85° 17′): Lithomarge of an inferior quality occurs on the north-western slope of a hill about 1¾ miles south-east of Gangadharpur railway station near Patharkatta village.

SAMBALPUR

(B. C. Roy)

The clays of Sambalpur district are of three types—sedimentary clays, china-clays and lithomarge. The sedimentary clays occur as beds mainly of Gondwana age, but at least two occurrences of clay beds in rocks of Cuddapah age are known. The china-clays have been formed either by alteration of granitic rocks or of schists at the edge of granites. The lithomarge occurs, of course, with laterite.

Sedimentary clays

Fireclays in Rampur coalfield have been prospected at Jorabaga and Darlipali by the Tata Iron and Steel Company. During the recent survey of the area further beds of fireclay were found at Rampur, Bundia, Katabaga, Kudopali, Ainlapali, Kirarama, Balpur, Chualiberna and Talabira. Others will probably be found when this area is mapped in detail. In addition, beds of good white plastic clay have been found in the coalfield.

Jorabaga (21° 47′ : 83° 52′): Numerous shallow test pits, besides a few shallow and deep borings, have been made by the Tata Iron and Steel Company around Jorabaga, where they have been working regularly since 1928, and during recent years about 1,000 to 1,200 tons of fireclay are reported to have been despatched to Tatanagar. A 2-foot 2-inch tramline conveys the material to Belpahar, B. N. Rly., a distance of about 4 miles. The contract price *f.o.r.* Belpahar was Re. 1-2-6 per ton in 1938-39. The quarries occur east and west of Jorabaga.

(*a*) Eastern quarries: In two quarries a 10-foot bed of fireclay dips 5°—10° towards the north, in sandstone.

(*b*) Western quarries: Five quarries have been worked. Fireclays have been exposed by these quarries along the side of a hill for a distance of 2 furlongs. Two well marked beds (upper 3 feet and lower 5 feet to 10 feet) are separated by an impure red sandy clay band (6 inches to 4 feet) dipping 5° towards the north-west. They overlie a bed of red ironstone, 3 feet thick, containing impure clays. In the plains below the hillock a 2 to 7-foot bed of fireclay occurs in two neighbouring quarries and below this occurs a series of dark carbonaceous shales with thin partings of dark fireclay (6 inches to 1 foot), coal bands (1 inch to 2 inches) and red and yellow clays (½ inch to 2 inches). Analyses of the main fireclay band (No. 1) and an underlying grey fireclay bed

* Recorded by Mr. Mukti Nath, Assistant Geologist, Geological Survey of India.

(No. 2) from the western quarries, kindly supplied by Messrs. Tata Iron and Steel Company, are tabulated:—

	No. 1.	No. 2.
SiO_2	51·98	51·64
Al_2O_3	33·85	31·34
Fe_2O_3	3·47	3·14
CaO	0·51	0·64
MgO	0·18	0·46
Total alkalies	0·26	0·46
Loss	...	10·74
TiO_2		1·84
Total	90·25	100·26

The main clay bed is reported to have a fusion point of 1,640° C, whilst the lower clay ranges between 1,600° and 1,625° C. A test made on a sample of clay from this locality gave the following results:—

Very hard; fine; plasticity good; colour (unburnt) dirty white; colour (burnt) white; linear shrinkage about 10 per cent; neither cracks nor fuses at about 1,400° C.

Darlipali (21° 46′ : 83° 51′): An outcrop of good fireclay was located in the *nala* sections, about half a mile north-west of the village. The bed is 2 feet thick between an overlying sandstone and underlying red clay bed dipping 5° north. Around the village indications of clay are common on the surface. A group of test pits spaced at intervals of 100 yards were put down by the Tata Iron and Steel Company south-west of the village. The fireclay bed varies in thickness from 9 inches to 10 feet, and is interbedded with practically horizontal or gently inclined ferruginous sandstones. The fireclays vary in colour from white to different shades of grey but are usually stained yellow or red due to iron.

Rampur (21° 46′ : 83° 55′): About half a mile north-east of Ram pur, on the eastern bank of the Ib river, occur two fireclay bed dipping 5° north-west. The upper bed of white clay is one foot thick, the lower grey fireclay is 3 feet. Tests made in the Geological Survey of India laboratory gave the following results:—

Very hard; fine; plasticity very good; colour (unburnt) dark grey; colour (burnt) dirty white; linear shrinkage about 10 per cent; neither cracks nor fuses at about 1,400° C; warps a little.

Bundia (21° 47′ : 83° 53′): A weathered dark fireclay bed is exposed at the junction of a small *nala* with the Ib on the latter's western bank, about three quarters of a mile north-east of Bundia. The sandstones dip gently, varying in direction from north to north-west. The

occurrence is presumably analogous to the fireclay near Rampur, as the distance is only three quarters of a mile.

Katabaga (21° 47′ : 83° 56′): The pit logs of the Rampur colliery near Katabaga record the presence of 'white clay' and 'white morrum' at shallow depths, which presumably indicate fireclay horizons. The average thickness of these clay bands is stated to be 5 feet.

Kudopali (21° 47′ : 83° 54′): One recent test well in the Kudopali village showed good fireclay debris at surface. The clay is reported by the owner of the well to have been entered at a depth of about 12 feet. The records of a borehole located about one furlong north-west of the well mentions a 6-foot 'chalk' bed, which apparently means fireclay, at a depth of 9 feet. The laboratory tests on this clay are given below:—

Very hard; fine; plasticity good; colour (unburnt) dark grey; colour (burnt) white; linear shrinkage about 7·5 per cent: neither cracks nor fuses at about 1,400° C but warps a little.

Ainlapali (21° 47′ : 83° 54′): Around a test well near Ainlapali, about half a mile south of Kudopali, there is fireclay debris together with carbonaceous shales, but nothing could be ascertained on account of water beyond the top 9 feet of murrum.

Kirarama (21° 46′ : 83° 53′): A small exposure of a grey fireclay, covered by murrum, is visible just west of the village of Kirarama on the cart track towards Darlipali.

Balput (21° 46′ : 83° 54′): Some samples of fireclay said to have come from Balput were brought for identification, but there was insufficient time for a visit.

Chualiberna (21° 49′ : 83° 53′): Grey fireclay was stated to have been struck in a small pit about half a mile south-west of Chualiberna.

Talabira (21° 44′ : 83° 58′): In a small hillock just north-east of Talabira fireclay is associated with sandstone, but no cuttings have been made to ascertain its extent and thickness. About half a mile east of the village, an indication of a whitish plastic clayey soil, slightly stained by iron oxides, is noticed alongside a tank, in an area of alluvium and laterite. A test pit might be sunk to determine whether this clay represents weathered fireclay at a shallow depth. Similar clayey soil has been observed over the fireclay beds around Jorabaga.

Baripahar (21° 46′ : 83° 47′): Clay beds occur interbedded with sandstones dipping 5°—10° N.W. at an elevation of about 350 feet above the plains in the hill 3 furlongs north of Baripahar village. They are exposed along the escarpment facing the village for about 40 feet along their strike. The following is the sequence from top to bottom of the section:—

30 feet—sandstone.

9 to 12 inches—high grade white clay.

5 feet—sandstone with 6 to 12 inches impersistent clay.

18 inches to 2 feet—good quality white clay.

Sandstone.

These clays presumably persist laterally around the hill. The difficulty in working them will be that if quarried the overburden will rapidly increase, whilst if extracted by underground mining, timbering costs will be high. The Belpahar station, B. N. Rly., is only 5 miles distant over easy country.

The results of laboratory tests on the clays are as follows:—

Upper band: Hard; fine; plasticity good; colour (unburnt) greyish-white; colour (burnt) white; linear shrinkage about 7·5 per cent; neither cracks nor fuses at about 1,400° C.

Middle and lower bands: Hard; fine; plasticity good; colour (unburnt) white; colour (burnt) white; linear shrinkage about 5 per cent; neither cracks nor fuses at about 1,400° C.

They could be employed either as refractory clays, or for glazed stoneware, tiles, etc.

Khola (21° 39′ : 83° 39′): To the south-east of this village in Bargarh subdivision, a bed of white clay with minor traces of creamy or yellowish clayey layers is associated with flaggy resistant ferruginous quartzitic sandstones of Cuddapah age which dip 15° north-west. The pits were infilled with water when visited. The local people have used this clay bed for domestic use. About 2 furlongs north of this clay exposure, a couple of tanks also show old white clay debris on their embankments and apparently thick white clay layers were encountered during excavation several years ago. The clay was tested with the following results:—

Soft; fine; plasticity good; colour (unburnt) cream-white; colour (burnt) greyish-white; linear shrinkage about 12·5 per cent; neither cracks nor fuses at about 1,400° C.

The area will be worth prospecting to determine the extent and thickness of this clay bed. The transport of the material would require cartage of about 18 miles to the nearest railway station, Jamga, B. N. Rly., involving a crossing of the Mahanadi river. The quality of the clay is good on account of its whiteness, plasticity, refractory properties, and freedom from grit, and it is, therefore, likely to find a ready market.

Lukopali (20° 46′ : 82° 33′): About three quarters of a mile east of Khoksa in Nawapara subdivision, a bed of white clay occurs in association with quartzites and cherts along the lower edges of a small plateau at about 50 feet above the plains. The bed seems to be somewhat puckered, probably by surface creep, but on the whole it may be considered horizontal. The bed is laminated and contains traces of rhombohedral chert. The clay had been extracted in the past by the neighbouring villagers within an area of about 300 feet by 100 feet, as could be judged from the minor subsidence caused by the removal of the clay layers. In recent years, the local people commenced fresh operations a little away from the old subsidence and have removed the clay, forming a cave measuring about 40 feet in length, 20 feet in width and 4 feet in height, along the clay bed. The entire thickness exceeds 4 feet. The clay is white, plastic, refractory, is usually free from grit and may be suitably employed for various industrial purposes. The area promises to yield considerable quantities of clay. The Raipur-Vizianagram branch of the B. N. Rly.

passes only a mile and a half away. The following is the result of the tests:--

Hard; fine; plasticity good; colour (unburnt) olive-green; colour (burnt) brownish-grey; linear shrinkage about 10 per cent; neither cracks nor fuses at about 1,400° C.

**Khinda* (21° 44′ : 83° 59′): A fairly extensive deposit of fireclay occurs at the base of a small hillock composed of Gondwana beds. The spot is about ¾ mile N.N.E. of Khinda. The clay occupies the base of Barakar sandstones near their junction with the underlying Talchirs. The bed strikes N.N.E.-S.S.W. and has a low westerly dip. It extends with slight interruptions for about a mile.

The fireclay is hard and compact. Normally it is creamy white in colour but sometimes it has rusty brown stains. At first sight the clay appears to be of good quality.

The deposit is being intermittently worked by Mr. C. P. Mishra of Sambalpur. The dimensions of Mr. Mishra's quarry are 77′×42′×7′ (deep).

The material is transported by bullock carts to the nearest railway station, Lapanga, which lies on the Jharsuguda-Sambalpur branch of the B. N. Rly., and is about 5 miles from the spot.

China-clay

The deposits recorded here are those recently inspected. Similar deposits have been reported from Dessar (21° 37′ : 83° 52′) and Pahar-sigira (21° 28′ : 83° 46′), and others will probably be found when the area is mapped in detail.

Ghichamura (21° 46′ : 84° 06′): About a mile and a quarter east of Ghichamura, china-clay stained yellow and red has been formed by the weathering of granite gneiss, associated with pegmatite and quartz veins which strike parallel with the gneissic banding. The gneissic banding dips steeply, between south and south-east.

Sagunpali (21° 35′ : 84° 01′): A pocket of china-clay, with traces of yellowish and greenish clay, resulting from the decomposition of gneisses and pegmatites, occurs about three quarters of a mile north of Sagunpali. The strike of the altered rocks runs approximately N.W.-S.E. The rocks have been kaolinised over a strike length of at least 30 feet, a width of 15 feet and to a depth of 70 feet, but the actual dimension of the altered rocks are probably considerably greater than this minimum.

Chuhukitikra (21° 39′ : 84° 09′): About half a mile north-east of Chuhukitikra, coarse-grained gneiss and pegmatite have been much altered over a large area. The strike of the gneisses ranges between W.N.W.-E.S.E. to W.S.W.-E.N.E., with dips either vertical or steep. The weathered gneiss is associated with occasional yellow and red impure but soft clayey bands of variable thickness. The coloured bands usually run parallel to the gneissic foliation planes and sometimes show minor contortions. At one particular spot the decomposition of the gneisses and

* Recorded by Mr. A. M. N. Ghosh, Superintending Geologist, Geological Survey of India, and Mr. Kedar Narain, Assistant Geologist, Geological Survey of India.

pegmatites was relatively uniform for about 100 feet along the strike and about 50 feet across the strike. A nearby creek section shows the persistence of this weathering beyond 8 feet from the surface. The actual dimensions of the kaolinised rocks, however, are several times larger. A small trial pit was sunk at this place to a depth of about 15 feet. Below about 5 feet of friable weathered gneiss, the rock contains about 50 per cent of good white clay. A network of coarse kaolinised pegmatite in the gneiss was encountered at the bottom of the pit, and the gneiss enclosed in this network has been altered by hydrothermal action to a gritless, fine-grained, creamy, soft rock, composed essentially of about 75 per cent of good clay. The pegmatites themselves, varying in width from a few inches to several feet, have been completely kaolinised. The upper part of the pegmatite is occasionally associated with loose, coarse residual quartz granules, whereas below they show an enrichment of good white clay. The altered pegmatites in the lower zone consist of over 90 per cent of almost grit-free, excellent white clay, with rare iron staining.

This area deserves careful prospecting, as it is the most promising so far examined in the district. The nearest railway station is Rengali on the Sambalpur branch of the B. N. Railway, about 8 miles away over flat country. The absence of any suitable nearby natural drainage will increase the cost of washing to some extent. The washed clay is of excellent grade, perfectly white, gritless and plastic.

Banjipali (21° 21′ : 83° 46′): Alongside the village tank a pocket of altered pegmatite is stated to have been prospected in the past for china-clay. A pit was apparently sunk for the purpose but it is now under water. The country is flat, consisting of a pink granite gneiss with quartz veins and pegmatites.

Piplipali (21° 22′ : 83° 36′): About two furlongs north of Piplipali kaolin had been extracted from altered granite-gneiss and pegmatite. The pits are now filled with water.

Katapali (21° 24′ : 83° 37′) : The country around Katapali is flat, with occasional rocky exposures of granite-gneiss which has been altered sporadically to kaolin. About a mile north-west of the village, the material is excavated for domestic use.

Baresinghari (21° 25′ : 83° 56′): A white clay quarry is located in flat country, just north of the reserved forest line, about a mile south-west of the village. The clay is carted to Sambalpur, about 5 miles by road. The pit has been intermittently worked by local contractors and when inspected was in active operation. The clay is derived from the alteration of quartz-sericite-schists and sericite-schists, which have been kaolinised by the adjacent granitic magma. The pit is 45 feet by 45 feet and has been worked to a depth of 17 feet. The upper 4 feet of soil gradually passes into whitish kaolinised schists. The strike of the schists varies between north and south to N.N.W. and S.S.E. and the dips are either vertical or steeply inclined towards the E.N.E. Minor quartz veins follow the foliation of the schists. The altered rocks are, as a rule, well cleaved and friable. The proportion of clay varies from 25 to 50 per cent of the bulk of the altered rock.

The process of refining is primitive and there is much room for improvement. The excavated material is placed in a small trough in the

pit with about twice the amount of water by volume, thoroughly stirred, and left to settle, the sandy particle sinking to the bottom. The clay sludge is then removed in earthenware pots and allowed to settle, and the water drained off. The clay is squeezed by hand and left to dry. The resulting material is white and is fairly free from grit.

The present contractor claims to have recovered about 2,000 maunds of clay during the 1939-40 season. Considering the thorough nature of alteration over practically the entire length, width and depth of the pit, it may be presumed that the deposit is fairly extensive, and others may be expected in this locality. The alteration of the schists is related to the granitic intrusion and presumably this alteration has taken place at other places along the granite margin. Mapping of the granitic rocks and the schists will be of help in future prospecting. The contractors are not finding a ready market for the clay. To a certain extent this is due to the crude method of washing but the clay is not plastic. On burning it retains its whiteness; its linear shrinkage is about 20 per cent and it does not crack but softens a little at about 1,400° C. The material when properly washed may be employed, perhaps, as filler in the manufacture of paper and textiles.

**Dangachhancha* (20° 54′ : 83° 02′): About a mile west of the village a small deposit occurs in a low hill near Dhabghat. The clay has resulted from the kaolinisation of granite and granite-gneiss and is quite white in places and yellowish to deep yellow at others. An inclined adit has been driven to an overall depth of about 80 feet in the white clay, which is used by the local villagers for various purposes.

White lithomarge

Akhradand (21° 39′ : 84° 12′): Deposits of white lithomarge, associated with ochre, occur half a mile north-west of Akhradand in the Nalibassa hilly regions bordering Bamra State. The nearest railway station, Rengali, on the Sambalpur branch of the B. N. Railway is about 10 miles west.

The deposits occur along a ridge of laterite striking W.N.W.-E.S.E. for about 6 furlongs in Sambalpur district, and continue in Bamra State for about the same distance with a width from 2 to 3 furlongs. The lateritised rocks are quartz-hematite-limonite rocks varying to nearly pure hematite with rare traces of manganese. The white lithomarge and ochre occur as bands in the lateritised rocks. The surrounding country is of granite-gneiss.

The lateritised rocks have been reported along the Nalibassa *nala* for nearly half a mile. White clays, associated with predominating red ochre, yellow ochre, pink and violet clays, occur in fairly well defined bands in the lateritised rocks. Dips are vertical or steep. Individual bands persist from 50 to 100 feet along the strike. The width of the bands varies from several inches to four feet and in some instances still wider bands may be anticipated. The depth to which these bands persist could not be ascertained from their exposures. The deposits have been

* Recorded by Dr. A. G. Jhingran.

traced at altitudes varying between the 950 and 1,050-foot contours and they probably occur at other elevations.

The area is likely to yield a considerable amount of white and coloured clays. Further search should be limited to the lateritised rocks, by means of trial trenches across the strike at regular intervals. Some test pits would provide evidence of the depth to which these bands usually persist.

The Nalibassa area around Akhradand, therefore, seems definitely promising but the inaccessibility of these deposits of white clay, red ochre and yellow ochre, the irregularity of the bands and the absence of perennial hill streams nearby, are discouraging factors for successful exploitation. The washed white clay is of excellent type, because of its white colour, fineness, plasticity and freedom from grit, and, if properly refined, it is likely to find a ready market. The red and yellow ochre bands, when properly washed, might also find a market. A sample of white clay with a pinkish tint after levigation, was tested in the laboratory of the Geological Survey of India and gave the following results:—

Colour (unburnt) pink; colour (burnt) yellowish-grey; linear shrinkage about 10 per cent; neither cracks nor fuses at about 1,400° C; brick is rather friable.

Future

It does not seem probable that a firebrick industry will be developed at present in Orissa, as there is no local market for such refractories. The Sambalpur clays are likely to continue to be railed to Jamshedpur. This, of course, is unfortunate as the province will not obtain the maximum benefit from this asset.

There should be scope eventually in Orissa for the development of the china-clays, but this scope will increase as the province becomes more industrialised. At present, increased mining of these clays will mean that they will be railed to other provinces for manufacture and the benefit of a possible ceramic industry lost to the province. It will be more to the ultimate benefit of the province if, after research, an attempt is made to establish a pottery industry at Berhampur, Sambalpur, or Cuttack. As the country becomes opened up more, and during the future geological mapping in the province, it is very probable that deposits of kaolin will be found from time to time.

CHAPTER XII

COAL

General

India's industrial development during the last century has been founded on the country's coal resources. The coal trade is of such dimensions that India has held for many years the position of the largest coal producer amongst the British dependencies. Most of the output in India has been from Bihar, whilst the output from Orissa has been

very small, all of it coming from the Rampur coalfield, Sambalpur district, where, since 1913, the yield has varied from 30,000 tons to 70,000 tons per annum, averaging about 40,000 tons. This may be compared with an all-India annual production of up to 28 million tons during the same period.

Coal had been known to occur in Orissa since at least 1837, when Lieut. Kittoe investigated the Talchir coalfield but this field was not mapped until 1856-57 by Messrs. W. T. and H. F. Blanford and William Theobald. Knowledge of coal in Sambalpur district dates back to 1854 and 1856, in the writings of Col. Haughton and of Capt. Saxon, but mapping was not undertaken until 1871, by V. Ball.

Active development in Sambalpur, on modern lines, was not commenced until 1909, and on the Talchir field in 1919—on the latter field, however, mining has been confined to Talchir State.

In Orissa there are four areas of Gondwana rocks: (1) the Rampur coalfield in Sambalpur, (2) the Talchir coalfield, part of which is in Angul, (3) the Athgarh basin in Cuttack and Puri and (4) the Khondmals basin.

The Rampur Coalfield, Sambalpur

(B. C. Roy)

This coalfield forms the eastern end of a basin of Gondwana rocks which extend north-west across Gangpur into the Central Provinces and Rewah.

The basement consists of Archean metamorphic rocks and granites. The Gondwanas consist of basal Talchir beds, followed by the Damudas and Mahadevas. The Damudas are divided into two series—the Barakars or coal measures below and the Hingir or (Kamthi) beds above.

Subsequent to the mapping of the field by Ball in 1871, systematic boring was carried out by King in 1884-86 in the Bagadia, Lillari, Baisundar and Dulunga valleys. The coal there proved to be of poor quality. Ten years later a coal seam was discovered at the site of the Ib river bridge during construction of the B. N. Railway. Exploration by the railway gave unsatisfactory results. In 1900, the results of an examination of the area by G. F. Reader were published by the Geological Survey of India. His advice was followed and, in 1909, the Hingir-Rampur Coal Company, Ltd., under the management of Messrs. Killick Nixon of Bombay, commenced operations at Rampur colliery south of Lamtibal. Later, a second colliery was opened up at Lajkura, working a second seam, the position of which with respect to the Rampur seam is uncertain. Coal has been produced continuously from the Rampur colliery since 1910.

Records of boring at Dhorlamunda (21° 50′ : 83° 50′) indicate three seams over 10 feet in thickness down to 690 feet with a fourth of 4 feet at 768 feet. Apart from the Rampur seam, and another seam called the Bungalow seam, said to be below the Rampur seam, the ash content of the other seams is over 30 per cent and accordingly they are of little

practical value except perhaps for domestic use. Analyses of the Rampur seam from the Rampur colliery are given below:—

	No. 2 pit, per cent.	No. 5 pit, per cent.	No. 6 pit, per cent.
Moisture ...	13·34	12·30	14·01
Volatile matter	31·65	35·73	36·59
Fixed carbon	55·70	49·23	49·61
Ash ..	12·65	15·04	13·80
Calorific value on dry sample, in calories ...	6,717	6,581	6,680

It will be noticed that the moisture content is high. An analysis done at Jamshedpur on a typical commercial sample from this seam, of which only the lower 7 or 8 feet are worked, gave: moisture 2·50, volatile matter 30·25, fixed carbon 51·25 and ash 16 per cent. This suggests that the coal loses moisture in transit.

An analysis of the 7-foot Bungalow seam at Katabaga (21° 48′ : 83° 56′) shows: moisture 9·80, volatile matter 28·44, fixed carbon 48·96, ash 12·80 per cent and calorific value 6,022 calories.

Reserves of the Rampur seam within an area of 20 square miles westward from Lamtibahal *nala* and north of Lilari *nala,* allowing for all losses, are estimated by Fox at 100 million tons, all of which will probably be within a depth of 600 feet. The property so far taken up by the Hingir-Rampur Coal Co., Ltd., covers 5 square miles and of this Fox estimates that 2 square miles contain workable reserves of 10 million tons in a 7-foot seam. There is, accordingly, considerable scope for further development on this field.

TALCHIR COALFIELD, ANGUL

(A. K. Dey)

A basin of Gondwana rocks extends from Talchir on the east to Rairakhol on the west, the centre being in Angul. The only part of the basin in which extensive prospecting and mining has been carried out is in the eastern part, in Talchir, over the Talchir coalfield. To date no mining has been undertaken in Angul and very little is known about the continuation of the seams there.

In this basin the Talchir beds at the base are 500 feet thick and form the type deposits for these rocks in India. The Talchir boulder beds contain striated pebbles indicating their glacial origin. They are overlain by 1,800 feet of Damuda beds which include the coal measures, and at the top are the Mahadevas aggregating 1,500 to 2,000 feet in thickness. The latter are probably equivalent to the Athgarh sandstones. As in the Rampur field, this Gondwana basin is usually bounded by faults.

Subsequent to its mapping in 1855-56 the field was not considered likely to prove of value as the exposed coal seams gave disappointing results on analysis. However, between 1919 and 1923, Messrs. Villiers,

Limited, of Calcutta, put down several borings in the field and within an area of 11 square miles near Talchir found two workable seams of coal. Analyses show them to be high moisture non-caking coals but suitable for locomotives.

Within Angul, places tested include Nisa (20° 56′ : 85° 00′), Kankarai (20° 58′ : 85° 00′), Raijharan (20° 57′ : 84° 58′) and Kosala (21° 00′ : 84° 56′). At all of these localities, boring revealed the presence of seams up to two feet or so in thickness, interbanded with carbonaceous shale. As these results correspond fairly well with some of those in the proved blocks immediately west of Talchir town, it is presumed that the seams in these two areas are similar.

Outcrops of coal in Angul are, however, rare. In 1855, when the field was examined, exposures of coal were found only at Patrapara (21° 05′ : 84° 46′). But the samples obtained from there were too poor in quality to be of value. On re-examining in 1940 the seams at Patrapara were found with the sandstones, shales and fireclay of the Damuda series for a distance of about six furlongs along the Madalia stream, west of the village. The beds are nearly horizontal. There are several seams ranging from 6 inches to 5½ feet in thickness. The 5½-foot seam thins out within a short distance. The Patrapara coal is interbanded with carbonaceous shale partings, and is of poor quality, not worth exploiting. An analysis of a sample of coal from this area is given below:—

Moisture .. .	9·90	per cent.
Volatile matter	35·70	„
Fixed carbon	38·88	„
Ash ..	15.52	„
Total ..	100·00	„

Does not cake; colour of ash—reddish brown.

Athgarh basin, Cuttack and Puri

(A. K. Dey)

A basin of Gondwana rocks extends south from Athgarh across the Mahanadi into Cuttack and Puri districts. In 1837, Lieut. M. Kittoe reported the occurrence of coal from near Sideshar hill about 6½ miles west of Cuttack. The adjacent rocks were examined by W. T. Blandford who believed that they were younger than the Damudas. The area was mapped by Ball in 1877 who found fossil plants proving the rocks to be of Upper Gondwana age. A basalt dyke cuts the beds at Sideshar hill. Although these rocks are stratigraphically above the Damuda coal measures, Ball pointed out that they may have overlapped the coal measures which, if present at depth, could be proved by boring, especially in the east-central part of the area. Ball, was not, however, sanguine of success.

The rocks in the neighbourhood of Sideshar hill were re-examined in December 1940 (see pages 45-6).

Some carbonaceous shales crop out in the gullies at the north-east base of the hill. Basalt is also seen here but is highly altered. The actual intrusive contact of the basalt and the carbonaceous shales is obscured by debris. The best exposures of the carbonaceous shales are along the bank of the Mahanadi immediately to the south of the basalt quarry. The beds dip 9° towards the south. The rocks contain traces of plant remains and grade to dark shales carrying here and there small lenticles of coal measuring about ¼ inch in thickness. It is said that a 6-inch seam of coal lies under the bank of the Mahanadi at this place and is only visible during the hot months when the water level is lower. Further up, at Bara Mundali (22° 27′ : 85° 45′), another outcrop of basaltic rock is seen along the bank of the river under a laterite cliff.

Ganjam

(G. C. Chaterji)

Outliers of Gondwana rocks have been found in the Khondmals, but so far these have not been mapped. The beds lie horizontally and include conglomerates, sandstones, grey and black shales with thin coaly bands, white shales and red ochre. Plant remains have been seen in the grey and black shales.

Coal has been reported from the region between Gochhapara (84° 00′ : 20° 29′) and Katrangia (84° 05′ : 20° 29′). A thin coal seam, about 2 feet in thickness, is said to have been found at a depth of about 35 feet from the surface while digging a well at Katrangia. The coal is said to have been burnt leaving about one-third of its mass as ash. A similar coaly band is also said to have been found about 30 feet below the surface at Gochhapara.

The nullah and river sections in the area do not show any definite outcrops of coal. About one-third of a mile north-east of village Kikijora (84° 01′ : 20° 28′), in the Sonamudi river section, about 20-22 feet of grey and black (carbonaceous) shales with thin coaly streaks are found between a conglomeratic bed below and a white sandstone and shale bed above, but there is no definite coal seam. Apparently coal has never been used by the people of this region. A thorough search of the Khondmals may, however, be successful in locating some coal deposits.

Future

The Gondwana basins of Orissa require to be mapped geologically on the modern 1-inch to 1-mile topographical maps. Although this mapping will provide very useful information, definite evidence of the value of these basins as coal producers can only be obtained by boring. It is a matter for decision whether this boring should be left to private enterprise or be undertaken by Government. At present there is no incentive for boring by coal companies, and it would be rather costly for Government to put down the large number of bore-holes that will be necessary. Prospects of success in the Athgarh and Khondmals basins are small, and in Angul they do not appear to be bright. The

Rampur basin will presumably be more widely developed as local demand increases in the future.

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CHAPTER XIII

GLASS-MAKING MATERIALS

General

Since 1914 there has been a gradual development in the glass making industry in India. However, even to-day imports of glass and glassware into this country are enormous, the minimum annual value being more than one and a quarter crores of rupees and occasionally exceeding two and a quarter crores. There is obviously scope for a very considerable local expansion in this industry. The development of a glass industry on modern lines in Orissa has, to date, been disappointing perhaps, as only one factory, near Cuttack, has come into existence.

Raw materials

The principal constituents used in the manufacture of glass are silica (usually quartz in one of its various modes of occurrence), and soda

(usually in the form of sodium carbonate known as soda ash, or sodium sulphate, known as salt-cake). The fusion of a mixture of these materials in correct proportions yields a rather soft and easily fusible glass, which is clear if the materials were free from such metallic oxide as iron oxide. A harder glass is made by adding calcium in the form of lime or limestone. If borax is added a clear optical glass results. To correct the greenish tint which may arise from the presence of iron oxide, manganese dioxide is used. Other decolourisers used include nickel oxide and selenium which are not available in India but are imported. Colouring agents may be added where special coloured glasses are required, such as manganese, chromates, cobalt, nickel and selenium of which all but the first two have to be imported.

In addition to the raw materials for the actual glass itself a reasonably cheap fuel is required, for which purpose the Indian coals are quite suitable. Refractory materials for the construction of the furnaces are also required.

Silica

As silica is easily the main constituent in the glass batch, it is obvious that the sand used must contain an absolute minimum of such impurities as are harmful to the resulting glass. Of these impurities the most serious is iron oxide and the amount of this present should not exceed 0·02 per cent if colourless glass is required, above this a decolouriser must be used and above one per cent the glass has a dark green colour. The presence of alkalies in the sand is not deleterious, as alkalies have to be added to the batch in any case. Also, within reasonable limits, the presence of alumina is permissible, particularly for those glasses in which a low coefficient of expansion, increased hardness, brilliancy and strength are required, but it tends to increase the viscosity of the glass melt, requiring a higher fusion temperature. Magnesia also increases the viscosity. Green bottle glass can be made from inferior sands rather high in iron.

The sand grains should preferably average 0·4 mm. in diameter and in any particular sand used there should not be extreme variation of very coarse material with very fine. However, the tendency has been to exaggerate the importance of grain size; sieving can reduce the extremes to a minimum. A coarse sand will naturally increase the period of fusion of the batch.

The determining requisite of a sand for glass-making purposes is, then, purity. Sands of the necessary composition are rare in India.

River sands could be used where they are fine-grained and of sufficient purity, but even the best of them are relatively high in iron and capable of producing only cheap glasses such as green bottle glass. Along most of the Orissa rivers, the sands would be too coarse and would require crushing, but occasionally, in some of the wider stretches, fine-grained and relatively pure sands are found. No deposit of this nature could be counted upon as a permanent source of supply from year to year.

Friable fine-grained sandstones, which can be easily crushed, are also used for glass-making. In Orissa most of the Gondwana sandstones

are fairly coarse-grained, but fine-grained types do occur. The Gondwana sandstones near Naraj (20° 28′ : 85° 46′) and also at the adjacent village, Talgar, on the Mahanadi, include such fine-grained friable varieties. Although they have rather a high iron content, they are used for the manufacture of cheap glassware at the Shree Durga Glass Works, at Barang, near Cuttack. Among the Cuddapahs and Archeans suitable friable varieties of sandstones may occur, such as the white friable quartzites near the estate bungalow at Dalapur (18° 46′ : 82° 19′) in Koraput. The following is an analysis of a specimen of quartzite from Dalapur:—

SiO_2	.	98·82 per cent.
Al_2O_3 etc.	.. .. .	0·62 " "
Fe_2O_3	. .. ...	0·32 " "
CaO	... .	0·06 " "
MgO	. ...	0·30 " "
	Total	100·12

Some of the quartz veins found associated with the gneisses around Motu (17° 50′ : 81° 24′) are relatively low in iron and may be utilised for glass-making.

Quite pure quartzites are known in the Cuddapahs and Archeans and numerous veins of quartz are scattered throughout the Archean rocks of the province, many of which, after crushing, could provide a quartz sand suitable for the finest quality glass. Unfortunately, however, the cost of mining, transport, and especially crushing of these rocks would be prohibitive to such an industry as is likely to be formed in this province.

Soda

Most glass manufacturers in India use a mixture high in soda, as the resulting glass has a low melting point and is easy to work.

Soda carbonate, known as soda ash, is now being manufactured in India in increasing quantities.

Limestone

The *kankar* deposits in Orissa would be too impure for use in glass manufacture. Analyses of samples of limestones from the Cuddapahs of Koraput and Sambalpur districts would indicate whether these are suitable for glass-making.

Manganese

Manganese-deposits have now been found in Koraput district and amongst these there may be a certain amount of chemical grade ore for use in glass industry. If not, manganese would have to be obtained from either Keonjhar or the Central Provinces.

CHAPTER XIV

GOLD

General

As in many other places in the north-eastern part of the Indian Peninsula, washing for gold is practised by local villagers along the stream courses in Sambalpur and Koraput districts and also in Angul, Cuttack district. The yield is only about two to four annas per day per individual, and washing is usually only done in the rainy season or immediately after heavy rains in the cold weather. No large alluvial deposits have been found which are likely to attract any mining concern with capital. Whether such occur, is doubtful, for not only must the gold be payable distributed consistently over a considerable area of alluvium, but also the relation of the alluvium to the underlying bedrock must be suitable.

The gold has been shed presumably from the veins in the adjacent country rocks. It does not necessarily follow that these veins could be payably worked for gold. The gold from the weathered and denuded veins becomes concentrated in the river sands and the actual amount of gold in the original veins may be extremely minute. So far no veins carrying payable amounts of gold have been found in Orissa.

Cuttack

(A. K. Dey)

The small quantity of gold collected in Angul comes from the Tikra *nadi* and its tributary, the Aunli. The experience of generations of gold-washers has enabled them to locate the places where operations are most payable. Gold-washing is carried on mainly during the rainy season; at other times it is practised only casually after heavy showers. The gold is mostly in very small particles.

Koraput

(A. M. N. Ghosh and A. K. Dey)

Dr. H. Crookshank, during 1933-34, investigated the gold occurrences of the Malakanagiri taluk and found gold-washing practised in the following areas:—

(1) In the Kolab river below its junction with the Rongpani.

(2) In the Rongpani *nadi* and its tributaries, the Jam and the Dharam Gedda.

(3) In the Garia *nadi* where it debouches from the hills close to Doraguda (18° 34′ : 82° 17′).

Gold is also said to occur in small quantities in most of the minor tributaries of the Jam and the Dharam Gedda, but this was not verified by Dr. Crookshank.

The gold is washed from the sands and gravels of the streams. Gold thus obtained consists of fine particles which concentrate with 'black sand' on panning. The metal appears to be very unevenly distributed. It was also found in an old bed of the Rongpani *nadi* about a quarter of a mile from the present river bed and there is, therefore, little doubt that it occurs almost everywhere at the base of the alluvium which covers the flood plains of the Rongpani and of the Kolab below its junction with that stream.

Dr. Crookshank did not, however, find any rich gold-bearing gravel exposed anywhere in the area examined by him. Every year after rains, it is found that the alluvium is washed away here and there exposing a few cubic feet of gravel. It is from these trivial deposits the gold-washers obtain most of their gold. From the information supplied by the headman of the gold-washers, Dr. Crookshank roughly calculated the value of the gold-bearing gravels from 1½ to 3 grains per cubic yard. The quantity of gold recovered by the washers is very small, the average earnings per person amount to annas two to annas three per day. Sometimes after heavy flood annas four per day may be earned. As alluvium is everywhere thick, there would be no hope of profitably working the gold deposited over the flood plains of the larger rivers. The source of the gold has not been traced. According to Dr. Crookshank, the source is in the large area drained by the Jam and the Dharam Gedda where the rocks are mainly biotite-gneisses and hornblende-schists. The fact that the gold here is found in most of the minor *nalas* suggests that it is widely disseminated through these rocks.

During December 1939, Mr. A. M. N. Ghosh visited the following localities where gold-washing is practised and has described three of them:—

Kollaru (18° 42′ : 82° 24′): Along a stream flowing into the Balia Gedda, which ultimately falls into the Jam *nadi.*

Battiguda (18° 39′ : 82° 24′): At certain places along the Jam *nadi.*

Dingiyaput (18° 36′ : 81° 15′): In the Dharam Gedda; the site is less than half a mile south of the village.

Govindpalle (18° 35′ : 82° 17′): At two places in the Garia *nadi,* south and south-west of the village.

Godiali (18° 34′ : 82° 14′): In the Rongpani river, north of the village.

Mandukali (18° 35′ : 82° 13′): In the Rongpani river, north-east of the village.

Kyangu (18° 37′ : 82° 08′): In the Kolab river, east of the village.

Salimi (18° 36′ : 82° 04′): In the Kolab, south of the village.

Govindpalle (18° 35′ : 82° 17′): There are two places where gold-washing is carried on in the neighbourhood of this village. One is about 6 furlongs south of Govindpalle in the bed of the Garia *nadi.* The yield here is reported to have diminished in recent years. The

other is on the north bank of the Garia *nadi,* about one and a half mile south-east of the village, where gold has concentrated in the sand and gravel on the convex side of the river, and is restricted to an area of only a few square feet. The bed of the river at this place is occupied by an exposure of dark hornblendic rock, which seems to be a band in the biotite-gneisses. The latter are riddled with quartz veins along the direction of schistosity. According to the washers this is the only place where washing is done nowadays, but the yield has diminished here in recent years and only a few grains of gold are obtained daily.

Kyangu (18° 37′ : 82° 08′): Gold-washing is conducted at selected places in the bed of the Kolab river, north-east and south-east of the village, particularly on the west bank of the river, about a mile E.S.E. of the village, and between Kyangu and Salimi (18° 36′ : 82° 04′), and still further west.

The western side of the river bed is occupied by well-jointed quartzites and sericite-schists striking east-west and dipping towards the south. They are transgressed by gneissic granites. The latter carry, along the planes of schistosity, pegmatite and quartz veins aligned east-west.

Kollaru (18° 42′ : 82° 24′): About two furlongs south-east of the Agency Rest House on the motor road, near milestone 18, gold-washing is occasionally carried on in the bed of the stream flowing south of the village. The river bed is occupied in places by decomposed schistose rocks, apparently the biotite-gneisses of the southern area but with the direction of foliation lying between north-south and N.N.W.-S.S.E. The gneissic rocks are covered by a mantle of fine silt and sand of variable thickness—evidently representatives of an old river terrace. Little information could be gathered about the gold occurrences here.

Most of the above localities have since been visited by Mr. A. L. Das Varma, a student of the Indian School of Mines, Dhanbad. He traced the source of the alluvial gold to the quartz veins associated with the granitic gneisses, hornblende schists etc. The amount of gold present in the quartz veins was found to be too small for commercial exploitation.

SAMBALPUR

(B. C. Roy)

The river sands and gravels over the metamorphic rocks of Sambalpur district have been long known as gold-bearing but no actual auriferous veins have yet been recorded in the associated rocks. According to early accounts, gold-washing was in progress last century along the Mahanadi. Ouseley (1) discussed as early as 1839 the process of gold-washing in the bed of the Mahanadi near Sambalpur. Kittoe (2) noted the presence of gold in many streams around Sambalpur town. Ball (3) observed gold on the Ib at Tahud (21° 36′ : 84° 02′), within the Talchir country, and according to him the gold was shed from either the gneisses or Talchir rocks. According to Maclaren (4), however, the source was from the Archean rocks. Even to-day the alluvium is washed for gold around Sonamohon (21° 46′ : 84° 13′), Dantamura (21° 43′ : 83° 56′), Hirakund (21° 32′ : 83° 56′) and other places. The alluvium

is all along river courses, the yield is small and of no economic importance to any but the local villagers.

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CHAPTER XV

GRAPHITE

General

Graphite is mined in many countries, but the best material is perhaps, from Ceylon and Madagascar. Small deposits have been mined in Orissa, in Koraput and Sambalpur districts, but this industry has lapsed in recent years mainly because of difficulty in marketing. The deposits in Sambalpur occur in a strip of country about 20 miles by 5 miles, in Nawapara subdivision and in a belt about 10 miles by 3 miles in Bargarh subdivision, both of them lying on the border of Patna State.

Two varieties of natural graphite are known—crystalline and amorphous. The crystalline variety occurs as soft metallic-looking black flakes. The amorphous material is a dull black fine powder, but the grains are minutely crystalline and not really amorphous.

Uses

Graphite is highly refractory and its principal use is in the manufacture of metallurgical crucibles. In recent years the use of graphite crucibles has rather diminished, not only because crucible steel is replaced by electric-furnace products, but also because certain artificial refractories have to some extent taken the place of graphite in crucibles. It still finds a use in the laboratory and in the melting of brass.

A large amount of graphite is required as a facing in foundry work, for which purpose the poorer qualities of amorphous carbon are suitable. Graphite is used also in the manufacture of pencils; for this purpose gritty material must be almost entirely absent. It is also used as a lubricant, when it is generally mixed with oils and, naturally, only the finest grades of graphite can be used. Graphite paint is frequently used on metal work. For electrical purposes, graphite is used in electrodes, dynamo brushes and also in dry batteries.

Manufactured graphite is now largely taking the place of the natural mineral for certain purposes.

Grades

The grades of graphite required in industry vary considerably. No deposits, as mined, consist of pure graphite; all contain variable proportions of impurities such as quartz, felspar, clay, mica, etc. For certain uses, as in foundry facing or paints, little further treatment than fine grinding is necessary. In other cases the quality must be improved to make it suitable, particularly for lubricants and crucibles.

The simplest form of beneficiation is by hand-picking and winnowing. Sometimes the material is crushed, then washed, the graphite being carried off on the surface of the water. Various methods of washing have been adopted. In recent years froth-flotation has been adopted and this provides the best product with minimum loss.

As a rule the graphite is concentrated to 80—85 per cent carbon content. This can be increased to 90—95 per cent by further fine-grinding and screening, thus removing impurities from between the laminae. Pure graphite can be obtained by treatment with acid, but the cost is considerable.

The methods of treatment in India are crude and the resulting product is rarely high-grade, a high proportion of the graphite being lost in the tailings. One of the troubles of much of the Indian graphite, which has restricted its use in crucibles, is that it usually contains a certain amount of fine mica which is difficult to remove in treatment. Such mica lowers the refractory properties of the materials.

Koraput

(A. M. N. Ghosh)

Occurrences of this mineral were noticed at two places in Koraput district: at Majikelam (19° 28′ : 83° 27′) about two and a half miles S.S.W. of Bissemcuttack railway station and at Chuchkona (19° 09′ : 83° 15′) nearly two and a quarter miles north of the motor road at Kumbhikotta (19° 07′ : 83° 15′).

Majikelam (19° 28′ : 83° 27′): Graphite occurs on the top of a hill about 500 feet above the level of this village nearly half a mile to the W.S.W. Khondalite, here, is intruded by a medium-grained, leucocratic biotite-granite. The graphite is found as narrow irregular veinlets and pockets in the granite, which is much decomposed and kaolinised near the pits. Sometimes the cleavage flakes are vertical, sometimes inclined or almost horizontally disposed. The thickness of the individual veins varies from three inches to one foot. The veins often anastomose and are not always continuous, pinching out and disappearing in places and reappearing in others. Although in general the graphite occurs in the granite, it is mostly found along the pegmatite veins cutting the latter. To a certain extent greisenisation has taken place rendering the granite slightly micaceous and impure.

The pits were sunk in the decomposed granite to a depth of nearly 20 feet, exposing 10 to 12 feet of kaolinised granite below the soil cap of a similar thickness, and a ton or two of the graphite has been extracted. The chance of getting any large deposit here does not appear

favourable. Further, the graphite is not of very good quality. Being near a railway station the deposit can, however, be worked by a petty contractor.

Chuchkona (19° 09′ : 83° 15′): Narrow bands of both acicular and massive graphite occur along the foliation of khondalite on the southern bank of a narrow stream, just south of the village. The graphite is fairly pure and appears to be of good quality. Three bands of the mineral were noticed of which the upper is 5 inches, the middle 3 inches and the lower one and a half inches thick. All the bands are within 3 feet of one another. The zone is folded along an axis running N 25° E—S 25° W and is exposed over a length of 90 feet along the river bank. Owing to the north-easterly pitch the zone descends to water level at its northern end. The veins are traversed along the cleavage by narrow veins of pegmatite, an inch or two in thickness, but this has not deteriorated the quality to any appreciable extent.

As the khondalite, in which the deposit occurs, is decomposed, it would not be difficult to drive trenches across the river bank to find how far the graphite extends on the southern side, since there is every likelihood of its continuing both along and across the strike.

Ambodala (19° 49′ : 83° 28′): About a mile south of Ambodala railway station some nests and nodules of impure graphite are found in the bed of a stream near its confluence with the Sakal *nala*. It is said that the graphite here was obtained from a pit sunk by the villagers some years ago. The pit has now been filled with river sand.

**Arugali* (19° 26′ : 83° 38′): Small bits of granular and flaky graphite were found scattered on the alluvium about a furlong S.S.E. of the village. A small pit sunk to a depth of five feet exposed small lenses and veins of graphite in highly decomposed gneiss. The material is of good quality though of limited dimension and can be worked on a small scale.

**Karriguda* (19° 35′ : 83° 42′): About one and half furlongs north of the village, veins of crystalline as well as amorphous graphite, measuring upto one foot in width, occur in garnetiferous felspathic gneiss. An excavation measuring 25 ft. × 9 ft. × 7 ft. deep yielded 20 bags of graphite.

**Sindiputtu* (18° 31′ : 82° 31′): A small nodule of graphite was found lying on the left bank of the Machkund river, about 3 furlongs west of the village and nearly 4 miles east of the Dudma Falls. A search in the khondalite country rock revealed the presence of minute flakes and thin films of graphite.

Unimportant small occurrences of graphite in granitic gneisses have also been recorded at the following localities: Jagadalpur (19° 46′ : 83° 33′), Kumbhiabhatta (19° 45′ : 83° 35′), Purutula (19° 47′ : 83° 34′), Dullerugam (19° 46′ : 83° 33′), Deppaguda (19° 43′ : 83° 28′), Dhanimaska (19° 51′ : 83° 33′), and Badegam (19° 54′ : 83° 30′).

* Recorded by Dr. A. K. Dey, Superintending Geologist, Geological Survey of India.

SAMBALPUR

(B. C. Roy)

Graphite has been located at Babupali (20° 39′ : 82° 44′), Gandamer (20° 38′ : 82° 45′), Baghmunda (20° 31′ : 82° 42′), Kumna (20° 30′ : 82° 42′) and Bilianjore (20° 28′ : 82° 42′). The mineral occurs as veins, pockets or bands in the garnetiferous gneissose schists, which are a variety of khondalite.

Babupali (20° 39′ : 82° 44′): About a mile E.S.E. of Babupali, in some recently ploughed land, scattered pieces of amorphous graphite in association with granite-gneiss, quartz veins and pegmatite were apparently encountered during ploughing, but the owner immediately covered the ground with *matti* fearing publicity. Presumably graphite occurs here in veins in the granite-gneiss.

Gandamer (20° 38′ : 82° 45′): A small outcrop of graphite-schist measuring about 4 feet by 4 feet is exposed in the ground two furlongs west of the village. The immediate vicinity is covered by alluvium except for occasional exposures of garnetiferous gneiss with quartz veins and pegmatites. A small pit was sunk on the graphite-schist to a depth of 3 feet, but it persisted in depth. It was not possible to ascertain the orientation of the graphite-bearing rocks but they are likely to occur as bands or pockets, following the foliation of the associated gneisses. The outcrop was composed of crystalline (needle) graphite with calcareous impurities. An average unwashed sample (sp. gr. 2·32), on analysis at the Geological Survey of India laboratory, gave the following results:—

Moisture	...	0·05 per cent.
Volatile matter	...	1·10 „ „
Fixed carbon	..	41·27 „ „
Ash	...	2·23 „ „
$CaCO_3$, $MgCO_3$	..	55·37 „ „
Total	..	100·02

Baghmunda (20° 31′ : 82° 42′): Some old pit debris, consisting of weathered fragments of felspar, garnet, biotite and traces of a needle variety of graphite, occur about a quarter of a mile north-east of Baghmunda, adjacent to the cultivated fields. The surrounding surface soil is deep and no other graphite-bearing rock could be observed. The Baghmunda pit was worked some years ago, before the construction of the Raipur-Vizianagram branch of the B. N. Railway, and is said to have yielded large quantities of graphite, but the enterprise was apparently given up because of transport difficulties.

Kumna (20° 30′ : 82° 42′): A pit alongside the main road nearly half a mile south of Kumna is reported by the villagers to have exposed some time ago veins of graphite, locally known as *surma*. At the time

of inspection, the pit was mostly filled in, but showed altered garnetiferous gneisses without any trace of graphite. About half a mile to the south and a furlong east of the same road, debris of decomposed garnetiferous gneiss showing traces of amorphous graphite was seen around another old pit. The work was apparently given up, as in the case of Baghmunda, owing to difficulty of transport.

Bilianjore (20° 28′ : 82° 42′): Near Bilianjore, just east of the Khariar road, an old pit was seen with debris of decomposed garnetiferous gneiss and traces of amorphous graphite. It is now mostly overgrown by jungle. The pit was worked many years ago before the construction of the present Raipur-Vizianagram branch of the B. N. Railway. The area is said to have produced large quantities of graphite, which in earlier days had to be carted great distances and presumably the enterprise was given up owing to transport difficulties. This pit, in common with other pits in the Nawapara area, has never been re-opened since the construction of the Raipur-Vizianagram branch of the B. N. Railway.

**Sargipali* (20° 55′ : 83° 05′): Near the northern outskirts of the village garnetiferous granite-gneisses carry veins of graphite along the planes of foliation of the gneisses dipping southwards at about 55° There are two veins within 200 feet of each other. The deposits are worked by Mr. S. P. Misra of Sambalpur.

The larger of the two veins is about 14 to 16 feet wide. It is worked by open cast method. The excavation along the strike of the vein was nearly 46 feet long and 20 feet deep in April 1944 and 126 feet long and 40 feet deep in April 1948. So far the width of the vein has been more or less consistent and both powdery and flaky varieties of graphite are obtained.

An average sample from the top six feet of the larger vein was analysed in the Geological Survey laboratory and gave the following results: —

Fixed carbon	33·28	per cent.
Volatile matter	3·06	„ „
Moisture	0.52	„ „
Ash	63·14	„ „
Total	100·00	

It is reported that the material shows some improvement at depth and graphite is obtained in pure form from time to time. Usually, however, the graphite mass is traversed by fine veinlets of quartz and felspar and narrow stringers of granitic material up to two inches in thickness. Occasionally tiny flakes of mica are present. In general the veinlets are parallel to one another but sometimes they send out branches which intersect. The veinlets dip southwards at an angle of about 70° which is slightly steeper than the dip of the gneissic country rock.

The other vein which lies about 200 feet further north consists mostly of flaky graphite. Here the country rock is more granitic than gneissose and the margins of the veins are not sharply defined. The

* Recorded by Dr. A. G. Jhingran and Mr. Kedar Narain.

width of the graphite bearing zone is about 9 feet. In April 1944 a pit was sunk to a depth of 12 feet in the graphite vein.

After quarrying, the graphite is left exposed for drying. Next it is hand-picked and sorted into three grades, depending upon the impurities present. The sorted material is then crushed and passed through sieves and is ready for despatch either in the powdered or or in the flaky form.

The nearest railway station Lakhna is about 45 miles away. Transportation to the railhead is done by bullock carts. Each cart carries a load of 10-12 maunds and takes 4 to 5 days in the journey to and fro.

*Debris of graphite were observed near several villages around Sargipali. The most important of these are Tentelkhunti (20° 57′ : 83° 07′), Dahigaon (20° 56′ : 83° 06′), Dangachhancha (20° 54′ : 83° 02′), Buren (20° 53′ : 83° 01′), Bardhapali (20° 53′ : 82° 59′) and Silatpali (20° 52′ : 83° 00′). The localities are situated in a belt about 10 miles long and two to three miles wide. The area appears to be promising for detailed prospecting.

Cuttack

†Disseminations of graphite occur in many of the hills of the Raigora ranges, especially near the Angul-Hindol State border. Nowhere, however, is the concentration of the mineral sufficient enough for commercial exploitation. About a mile and a half a little west of south of Kanja (20° 39′ : 85° 07′), a small deposit of flaky graphite was found in the khondalites. Here four thin bands of graphite, varying in thickness from 9 inches to nearly 18 inches, are found within a zone about 16 feet wide. The quality, however, is very poor as shown by the following analysis:—

Fixed carbon	6·94 per cent.
Ash	88·56 „ „

Future

The deposits in Koraput are very small indeed and, individually, are of negligible value. The fact of their occurrence here does raise hopes that in the future workable deposits may be found in this district.

The graphite belt south of Padampur (21° 00′ : 83° 04′), in the Bargarh subdivision, Sambalpur district, has not yet been fully explored. The deposit at Sarigipali appears promising and should be tested to determine its extension in depth. Other pits in the neighbouring localities should be re-opened with a view to gauge the possibilities of the area, which has remained till now somewhat inaccessible.

In Nawapara subdivision, Sambalpur district, the graphite pits appear to have been abandoned because of distance of transport. Now that the Raipur-Vizianagram railway has been opened, however, transport difficulties will be lessened. The old pits should be re-opened to determine their extent both laterally and in depth. Further work in this area will also probably bring to light additional deposits.

* Recorded by Dr. A. G. Jhingran.
† Recorded by Mr. S. Krishnaswamy.

From the descriptions, the deposits do not appear to be of high-grade graphite and the mineral will need to be concentrated. Apart from a certain amount of hand-picking at the pits, it would probably be cheaper if concentration were done at a central place to which the mineral could be sent from both Sambalpur district and Koraput. A suitable locality may be found along the Raipur-Vizianagram railway. Such a plant might advisedly be erected in conjunction with the manufacture of crucibles or other graphite products requiring a high grade of graphite.

However, no extensive industry is likely to arise, and it can only be of moderate dimensions depending upon the supply of raw material available and India's small but growing demand for graphite products.

CHAPTER XVI

IRON-ORE

General

As in other parts of India, village *loharis* have smelted local deposits of iron-ore throughout Orissa for many centuries. Imported iron can be cheaply purchased nowadays, but local iron smelting is still in progress in the more inaccessible areas such as the hill tracts of Ganjam and Koraput. The ore used by the *loharis* is mostly soft earthy lateritic limonite, earthy hematite or decomposed quartz-magnetite-schist of an inferior grade. High-grade hard iron-ore, even where available, as in the Hirapur hill, Koraput, is not used as it cannot be smelted in the village furnaces.

From the point of view of modern iron smelting, in India, the material used by the village *loharis* is of no value. In Bihar, and in Keonjhar and Mayurbhanj, immense deposits of high-grade iron-ore are cheaply mined and smelted. Raw material for any new iron and steel industry in other parts of India must compete with these deposits.

In Orissa deposits of high-grade ore have been found at Hirapur hill some 5-6 miles west of Umarkot (19° 40′ : 82° 15′) in Koraput district, whilst several smaller deposits of rather lower grade ore have been found in Sambalpur district. At Hirapur there is a minimum of 10 million tons of ore available ranging up to 62·7 per cent iron and perhaps averaging 60 per cent. In Sambalpur the deposits are widely scattered and average 55 to 60 per cent iron.

Cuttack

(A. K. Dey)

Iron-ore is found on a small hill about half a mile E.S.E. of Khardih, a village about 3 miles S.S.E. of Sukinda Khas (20° 58′ : 85° 55′) and about 18 miles by road from Jajpur Road Station. Khardih has been wrongly shown on the topographical map as Kharipadia. The top of the hill is of quartzite, but detrital iron-ore, associated with debris of quartzite and banded hematite-quartzite is found scattered on the slopes. The ore was seen *in situ* only at one place near the base of the hill, on the south, over an area about 100 feet in length and 15 feet in width. It consists of magnetite and hematite, grading into banded

hematite-quartzite. It is difficult to estimate the total quantity of ore available without knowing the depth of the detritus throughout, and also that of the solid ore, but the amount does not appear to be large. When tested, magnetite ore showed 69·38 per cent Fe, and hematite ore 66·6 per cent Fe. According to Mr. G. P. Rath, deposits of iron-ore consisting of hematite apparently of good quality are found in abundance on the Tomaka range near Champajhar (21° 04′ : 85° 56′), Patwali (21° 06′ : 85° 58′) and Tungaisuni (21° 03′ : 85° 53′). Ores of poorer quality and also of lateritic type are present near Hatimunda.

In Angul iron-ore worked by the villagers consists of concretions of hematite, and to a very small degree limonite, weathered from the Damuda sandstones and shales. Only the softer varieties of ore, such as can be easily reduced to powder, are used. These generally occur in superficial deposits and are either picked up from the surface or collected from shallow diggings. At Similipal (21° 04′ : 84° 47′) deposits occur about two miles north-east of the village along the banks of the *nalas*. At Brahmanbil (21° 03′ : 84° 56′) the ore is found along the bank of a stream about a mile N.N.W. of the village. Mr. S. Krishnaswamy came across a small exposure of low-grade hematitic iron-ore in a low oval mound to the north of Kaniabera (20° 51′ : 85° 09′). He also observed clay ironstones from within the metamorphic country in and around the village of Joragaria (20° 50′ : 85° 15′). Similar deposits are found at several other localities. Such deposits are small and can only be worked on a small scale by local iron smelters.

Ganjam

(G. C. Chaterji)

Slag from ancient iron-furnaces is found scattered on the ground in several parts of Ganjam. In certain localities where iron-ore has been reported and where slag is found, such as Kaladharoparbata near Kullada (19° 58′ : 84° 38′), Bori (19° 45′ : 84° 35′) and Barada (19° 40′ : 84° 21′) in the Ghumsur subdivision, a few nodules of limonite and hematite as well as some manganese minerals derived from the weathering of gneissic rocks occur. Some very poor limonitic ore is also found in the laterite of various parts of the district.

In the Khondmals iron-ore was reported from the area between Gochhapara (20° 29′ : 84° 00′) and Katrangia (20° 29′ : 84° 05′) but consisted of ferruginous Gondwana sandstones, and of hematite pebbles derived from a conglomerate occurring in the same formation.

These iron-bearing materials were at one time collected by the village smiths and profitably smelted. Ploughshares manufactured over a hundred years ago from iron derived in this way are still giving excellent service. Apparently the smiths had unknowingly manufactured manganese-steel from a mixture of nodules of iron and manganese minerals.

Koraput

(A. M. N. Ghosh)

Iron is smelted by local blacksmiths in many villages scattered over the district. Most of the localities recently visited for iron-ore were

found to contain material useless for modern furnaces. The only place where moderately good quality limonite and medium grade hematite were obtained was at the hill known as Hirapur *dongri*, about 5½ miles south-west of Umarkot (19° 40′ : 82° 15′) and three miles south-west of Kumari (19° 38′ : 82° 14′).

Hirapur Hill: The hill is aligned E.S.E.-W.N.W. for nearly 10 miles, and is about two miles across at Ghumar. The highest point is over 3,000 feet above sea level and about a thousand feet above the general level of the country. The iron-ore occurs on the northern slopes of the central portion of the hill for a length of a mile and a half.

The plain country below the hill is of granite-gneiss extensively traversed by pegmatite and quartz veins. The gneiss seems to have been intruded by a coarsely crystalline porphyritic granite, although as an alternative the latter may be regarded as a non-foliated phase of the granite-gneiss. The north-central side of Hirapur hill is of coarse and fine quartzite carrying thin bands of hematite and may be described as banded hematite-quartzite. The quartzite seems to be underlain by epidiorite and associated basic rocks, of which hornblende-schist and a dark coloured granulite are by far the most common. The epidiorite is possibly folded along an axis lying between east-west and E.S.E.-W.N.W. The epidiorite is traversed by veins of granite and pegmatite.

The iron-ore occurs in the banded hematite-quartzite and has probably been concentrated by replacement of the quartz in the quartzite. The iron-ore occurs along the central portion of a synclinal fold, the outer limbs of which are occupied by epidiorite and amphibolite. The disposition of the hematite band is roughly E.N.E.-W.S.W., but the strike of the hematite, when *in situ,* and of the underlying epidiorite, is between N.W.-S.E. to W.N.W.-E.S.E. The dip of the rocks is northwards.

The iron-ore is found on the top of the first row of hills north of the main range, and occurs at heights of 300-400 feet above the general level of the country but in places reaching a height of 500 feet. The deposits never form conspicuous ridges, but occur on the dip slope of the epidiorite and granite to the south. The dip slopes on the northern and north-eastern sides of the ore-bearing hill are covered by float ore, consisting of pure and siliceous hematite, limonite and earthy limonite. The soil cap is also thick in places, and the float cannot always be seen; at two of the many pits at the north-eastern end of the band, solid ore was noticed under five feet of soil.

Owing to solution and leaching the main band has sagged and is consequently disturbed so that the thickness cannot always be determined from the outcrops. Available exposures give a minimum and maximum thickness of 40 and 100 feet respectively. The thickness is a maximum at the centre (known as Beluapani to the local people) and pinches out on either side. At Beluapani the thickness is 75 to 100 feet, and to the south-east is 50 feet. The average thickness is about 50 feet. The width of the exposure varies from 200 to 300 feet near its centre narrowing at the two extremities. The superficial area over which the ore is distributed is roughly two million square feet. The specific gravity of the ore—as determined from six samples—is 4·0. The quantity of iron-ore for every ten feet of depth, therefore, amounts to 2,000,000

tons, and 10,000,000 tons for 50 feet. This should be regarded as a conservative estimate of the quantity of the ore in sight as the deposit is likely to continue at depth. Float ore has been left out of these calculations. It was not possible to explore the whole area and there seems no reason why the ore should not extend further west.

At the surface the ore is medium to low grade hematite, which often has a coating of limonite. The better grade ore—mostly hematite—occurs in the centre (Beluapani) and eastern part (Kumri) of the band. On the western side (Punjipakna and Amba Devi) the ore is hard and soft limonite. There is thus progressive limonitisation of the ore from the eastern to the western end. Analyses of samples from different parts of the ore-body are as follows:—

Locality	Ore	Iron per cent	P_2O_5 per cent	Specific gravity
Beluapani pit, east of Tilondi	Hematite	62·70	0·23	4·27
Hillside east of Beluapani ...	Hematite	60·50	0·38	4·02
Punjipakna, east of Tilondi ...	Hematite	61·05	0·29	4·09
Beluapani	Inferior Hematite.	56·10	n.d.	3·94
Beluapani from a pit	Do.	54·45	n.d.	3·69
Punjipakna	Limonite	49·50	n.d.	3·07

The deposit does not compare with similar iron-ore deposits in Bihar. It is not possible, however, to give a final opinion as the entire hill was not explored. As matters stand at present the prospect of working the deposit for export will continue to be remote unless transport facilities in the district are improved. At present a fine-weather motor road connects Umarkot with Nowrangpur but there is no proper road from Umarkot to the iron-ore localities. To add to the comparative inaccessibility of the deposit it is remote from the rail-head. The ore might, however, be smelted locally for pig iron by means of charcoal. Under careful conservation the large *sal* forests in the north-eastern parts of the district are capable of furnishing an abundance of charcoal for the purpose. Limestone is also available in the district.

Santemra (19° 38′ : 82° 32′): Low grade iron-ore occurs on a hillock about 2½ miles south-east of Santemra and is worked by local blacksmiths. The ore consists of limonite and earthy hematite and seems to occur along a shear zone of quartzites and ferruginous shales and slates. Sometimes brecciated material has been replaced and cemented by concretionary hematite and fibrous and radiating limonite. The deposit is very limited in extent and the blanket of laterite is nearly 50 feet thick. The deposit is unlikely to be of value other than as a source of iron to the local iron-workers.

Garbarai Hill (19° 29′ : 82° 35′): Scattered pebbles of lateritised quartzite, in which there has been some concentration of hematite and limonite, occur on the top of this hill, which is of grey and white quartzite. The pebbles were formerly collected by local iron-workers for smelting.

Madhugulimi (19° 19′ : 82° 49′): Superficial limonitic earth, formed by the decomposition of acid and basic gneisses on the northern slope of the hill just south of Madhugulimi, is used locally for smelting iron.

Gunnayyapada (18° 35′ : 82° 32′): Formerly the local iron-workers used laterite here for smelting.

Siraguda (18° 31′ : 82° 08′): Decomposed micaceous hematite, limonite and ferruginous earth have been quarried about half a mile S. S. W. of Pangamu Rest House, and ¾ mile east of Siraguda. A number of pits, with slag heaps nearby, suggest that iron is smelted occasionally by the local people. Granitised biotite-schist (biotite-gneiss) crops out nearby.

Doraguda (18° 47′ : 82° 21′): The villagers of Doraguda and neighbouring hamlets have made several excavations at the foot of the eastern and north-eastern sides of hill 2140, about ¾ miles south-west of Doraguda. Some of the pits are 10 to 12 feet deep, and narrow underground tunnels have been driven. The ore is a low-grade micaceous hematite with much quartz, and occurs in a fine-grained banded granulitic rock, the constituents of which have been partially replaced by impure hematite. The rock forms a thin band on the eastern side of the hill and scattered pebbles, showing hematite, occur as float on the low ground. The quantity of ore is not large and the quality is poor. The southern side of this hill has a thin mantle of laterite, which would provide a better substitute for smelting.

Ferruginous earth is also obtained at the north-eastern edge of Dharamgod Reserve Forest. The occurrence is on a low mound about three furlongs south-west of milestone 6 on the road to Ramagiri.

Chitra (19° 04′ : 82° 29′): The iron-ore which occurs at the foot of a hill about a mile east of Chitra (19° 04′ : 82° 29′) in the Kotpad thana, consists of soft bands and nodules of hematite occurring along a fault rock in the Cuddapah shales.

Daipara (18° 21′ : 82° 14′): According to Dr. H. Crookshank, iron-ore (hematite-rock), smelted by the villagers here and there along the western border of the charnockite range in the Malakanagiri taluk, is probably derived from the weathering of ultrabasic rocks. The best deposits are found north-east of Daipara (18° 21′ : 82° 14′). This ore was tested for vanadium and chromium but with negative results.

Iralagondi (18° 17′ : 81° 42′), *Metteruguda* (18° 15′ : 81° 35′), *Singanguda* (18° 13′ : 81° 32′) and *Kalimala* (18° 04′ : 81° 45′): Dr. Dey visited four iron-ore localities in Malakanagiri. They are:—(1) half a mile south of Iralagondi; (2) half a mile south-west of Metteruguda; (3) one and a quarter miles south-west of Singanguda; and (4) about 3 furlongs E.S.E. of Kalimala. At all of these places the ore is essentially limonite which has been derived from the alteration of basic and ultrabasic rocks. A specimen of limonite from Iralagondi gave 20·74 per cent Fe_2O_3 on analysis.

Gaudavalasa (18° 28′ : 83° 00′): Debris of titaniferous iron-ore found scattered on the surface soil of a hill about two furlongs W.N.W. of Gaudavalasa (18° 28′ : 83° 00′), was tested by a small excavation but no ore body was found *in situ*.

PURI

(G. C. Chaterji)

In this district laterites have been used for local smelting in the villages. Along the shore of Chilka lake, near Jatia hill (19° 41′ : 85° 12′),

there are occasional beds of concentrated magnetite sand, sometimes up to 2 feet in thickness, but these are of no value as a source of iron.

Sambalpur

(B. C. Roy)

Ten small occurrences of iron-ore have been examined, scattered irregularly over the district, and further discoveries are anticipated during the course of geological mapping. These deposits occur generally on small linear ridges or *dungris*, or sometimes as scattered lateritic debris on hill-slopes. The ores vary in composition from hematite-quartz-limonite-rock to nearly pure hematite, with rare traces of pyrolusite, psilomelane and wad. The average ore contains 55 to 60 per cent iron, 0·76 per cent manganese and 0·31 per cent phosphorus. The deposits are usually of superficial laterite, capping granite-gneiss or ferruginous quartzites. The occurrence of fault-breccia suggests that the lateritised hills often indicate shear zones; at Kot (20° 15′ : 82° 34′) a warm spring is located on one such zone. Some of the deposits are even to-day utilised by the local *loharis*. The small and relatively low grade deposits are unlikely to be used for modern iron-smelting in view of the rich deposits of Singhbhum and Keonjhar. The localities and reserves, allowing 10 cubic feet of ore per ton and 15 feet depth of ore-body, are detailed below:—

1. Lohakhand (21° 41′ : 84°9′), just south of the village	5	million	tons.
2. Akhradand (21° 39′ : 84° 12′), in Nalibassa hill	15	„	„
3. 1 mile south-east of Khirapali (21° 90′ : 82° 57′)	3	„	„
4. Two miles south-east of Mahuabata (20° 47′ : 82° 34′)	1	„	„
5. Quarter of a mile west of Kholigaon (20° 34′ : 82° 34′) ...	5	„	„
6. Half a mile west of Majhgaon (20° 35′ : 82°34′)	5	„	„
7. One furlong east of Bindrabahal (20° 21′ : 82° 34′)	Small.		
8. Two furlongs south-west of Padapali (20° 20′ : 82° 46′)	1	million	tons.
9. Kotgaon (20° 15′ : 82° 34′) ...	4	„	„
10. Half a mile north of Chikalchua (20° 14′ : 82° 33′)	3	„	„
Total ...	42	„	„
Add—10 per cent for unestimated deposits and 10 per cent for float ...	8	„	„
Total reserves ...	50	„	„

Specimens of fine-grained magnetite and ilmenite from around Mundher (21° 21′ : 84° 05′) have been identified but the area has not yet been examined. They contain traces of nickel, but no vanadium could be detected.

Future

The Hirapur ore-body, although of quite high grade, is not comparable in size with the deposits of Singhbhum and Keonjhar. Still, under certain conditions, it is large enough to support a small iron-smelting industry. However, the deposit is rather inaccessible and transport charges would be considerable. It does not seem likely that a small industry based on these ores could be commenced in the near future, comparable with the State iron and steel industry in Mysore, but, should Koraput district itself develop, then an iron and steel industry may become feasible here. Limestone as flux is available in the district, but coke would be costly and the utilisation of the local forest for charcoal would be necessary. Should hydro-electric power become available then the establishment of a small iron and steel industry is likely to be hastened.

In Sambalpur district the deposits are small and scattered, and the ores are not of very high grade. Although limestone is available the Rampur coal is not of coking quality, and coke or coking coal would have to be brought from the Bihar coalfields. It does not, therefore, appear likely that any iron and steel industry based on Sambalpur ores could compete with the Jamshedpur industry in the near future.

CHAPTER XVII

LIMESTONE

General

One of the principal raw materials necessary for the development of a country's industry is limestone, as it provides lime and cement which form the basis of building construction. India is well endowed with deposits of limestone, and cement works have been erected in many parts of the country. In Orissa, however, only surface deposits of *kankar* and the coastal beds of *ghootin* have been used as a source of lime for building purposes. In recent years the re-examination of the Dungri area in the Sambalpur district has brought to light large reserves of limestones suitable for the manufacture of cement. Attempt may be made to utilise the limestones by erecting cement works at a suitable site within the district.

The superficial deposits of *kankar* have been noted already under 'Building Materials'. In this chapter the deposits of bedded limestone will be described, such as may later find a use for the manufacture of cement or for other purposes.

Uses

The simplest use of limestone, including also marble, is as a building stone. However, in Orissa, no limestone is quarried for that purpose.

In India large amounts of limestone are burnt annually for use by the building trade as lime for mortar and plaster. Much limestone is required as a flux in the iron and steel trade. A certain amount of lime is necessary for the manufacture of glass. Very pure lime is required in the chemical industries, particularly in the manufacture of bleaching powder. It is also necessary in the manufacture of calcium carbide and calcium cyanamide; the latter is an important nitrogenous manure which would find a market if available in India. Perhaps the largest amount in India is now used, however, in the manufacture of Portland cement, which is made by fusing limestone with suitable clays.

Composition

For use as building stone the composition of a limestone is immaterial—its durability, appearance, ease of working, and price are the only considerations.

Limestones which are burnt to form lime, for use in mortar and plaster, need not necessarily be particularly pure, in fact in some cases certain clay impurities may improve the qualities of the burnt product for use as mortar. A very impure form of calcium carbonate is *kankar,* which occurs as a surface deposit in many parts of the province and is collected and burnt; the clay and other impurities are frequently in such correct proportions that the resulting hydraulic lime has practically the properties of cement.

For use in chemical industries, a very pure limestone is essential. The presence of relatively chemically inert material like quartz is not particularly detrimental although its absence is preferred, but a high percentage of iron and alkalies is not permissible. The iron, if possible, should be below 0·20 per cent., and the combined impurities less than 1 to 2 per cent.

In the glass industry a high degree of purity is also essential. Free quartz is unimportant as also are the alkalies, as they enter into the composition of the glass in any case, but magnesia and particularly iron are undesirable. The alumina content should be low.

Limestone used in the iron and steel industry need not be low in magnesia and iron. Silica and alumina are the main impurities to be avoided for they add considerably to the slag formed in the smelter. At times, however, as in treating a high alumina iron-ore, a little silica in the limestone is permissible.

In the manufacture of cement considerable amounts of silica and alumina, within reasonable limits, are permissible in the limestone, for they have, in any case, to be added to the kiln charge in the form of clay. However, they must not be so excessive as to make it impossible to adjust the limestone-clay mixture to that necessary for the composition of the required cement. Magnesia is undesirable in the limestone and should not be greater than 2·0 per cent. Iron in the limestone should not normally exceed 2·0 per cent. Alkalies are driven off in the flue gases and, indeed, provide a source of potash in some countries.

Koraput

(A. K. Dey)

Limestone deposits are known to occur in the Cuddapahs in the vicinity of the Sabarai river, some 18 miles west of Malakanagiri. They extend about one mile along the bank of the river, about 3 miles west of Kottametta (18° 20′ : 81° 42′). These beds of light grey and cream-coloured limestone vary from 10 to 20 feet in thickness, and are either horizontal or dip at a very low angle. The limestone from near Kottametta is of excellent quality as can be judged from the following analysis:—

SiO_2	1·84
R_2O_3	1·24
CaO	53·36
MgO	0·59
CO_2	42·59
SO_3	Nil
H_2O	Nil
P_2O_5	Nil
Total	99·62

Analyst—T. R. Seshadri

South of the deserted village of Nandivada (18° 19′ : 81° 40′), the limestones are dark grey and argillaceous for a distance of three quarters of a mile, beyond which they become interbanded with phyllites.

Argillaceous limestones associated with purple shales and slates, also of the Cuddapah formation, occur along the Kolab river near Guptesvara (18° 49′ : 82° 10′) and Sirivada (18° 50′ : 82° 10′). Near Guptesvara caverns and hollows have been formed in the limestones, including the sacred cave of Guptesvara where the Sivarathri festival is held annually in February-March. Good examples of stalactites and stalagmites are found in the cave temple.

Near the roadside, about one and one-eighth miles north-east of Guptesvara, a band of more or less argillaceous limestone which occurs associated with shales has been traced for a distance of two furlongs north-east along its strike.

At Sirivada a grey dolomitic limestone is exposed in the bed of the Kolab and along its banks for a distance of about one mile.

It contains tiny concretions of clay and grades to shales with calcareous concretions. An analysis of a specimen of this limestone shows:—

SiO_2	... ...	3·58
R_2O_3	... ...	0·15
CaO	... ...	29·54
MgO	.. ..	20·78
Loss on ignition	. .. ...	46·27
	Total ..	100·32

Deposits of limestone occur at Kondajodi (18° 57′ : 82° 15′) in Kotapad. The limestones are associated with purple and white Cuddapah shales and occupy small isolated hills striking in directions lying between N.E.-S.W. and E.N.E.-W.S.W. The dips are rather steep. Several bands of limestone over 100 yards in width are present. Some of the outcrops could be traced for a distance of over two miles along the strike. The rocks are usually purple with a nodular texture. At Kondajodi proper, the limestones have a mottled appearance, the prevailing colours being red and white. The limestones appear to be dolomitic and grade into shales which are often fractured. Small crystals of quartz and secondary silica are frequently found as infillings of cracks and fissures in the limestones. The deposits are promising and admit of exploitation when better facilities for transport are provided. At present the limestones are used on a small scale for the manufacture of lime locally. A sample analysed shows: 14·72% insoluble, 0·20% R_2O_3, 25·35% CaO, 19·18% MgO and 39·30% loss.

Sambalpur

(B. C. Roy)

Extensive deposits of limestone and dolomite, suitable for lime-burning, fluxing in the iron and steel industry, and cement making, occur in the Sambalpur district. Such deposits have been located at Sulai (21° 58′ : 84° 06′), Padampur (21° 45′ : 83° 34′), Lakhanpur (21° 38′ : 83° 37′), Dungri (21° 42′ : 83° 34′), Sauntmal (21° 41′ : 83° 33′), Badmal (21° 40′ : 83° 33′) Behera (21° 39′ : 83° 32′), Banjipali (21° 38′ : 83° 30′), Kusumda (21° 37′ : 83° 30′), Putka (21° 10′ : 82° 58′), and Silhatpani (20° 36′ : 82° 35′).

Sulai (21° 58′ : 84° 06′): Dolomitic limestone occurs about 2 miles north of Sulai village near the Gangpur State border, and is exposed practically all along the Sapai *nadi* for about 3 furlongs. The deposit is a continuation of one of the beds of dolomitic limestone which occur in Gangpur State, and comprises massive and flaggy medium to fine-grained dark rocks. Generally the beds strike E.N.E.-W.S.W., dipping moderately towards S.S.E., but are more disturbed to the east. The limestone abuts against a coarse pegmatite cropping out south of the deposit at the *nadi*. The main bulk of this strip of limestone lies in Gangpur and

only a small portion occurs in Sambalpur. The outcrop is about 3 furlongs along the strike, and one furlong across the strike. Assuming a workable depth of 50 feet (the deposit occurs in flat country), on the basis of 12·5 c. ft. per ton, 5 million tons are available on the Sambalpur side of the border. Perhaps one-third of this will be of good quality. A specimen from a typical flaggy limestone band, assayed in the laboratory of the Geological Survey of India, gave the following results:—

SiO_2	3·40
Al_2O_3	0·02
Fe_2O_3	0·78
CaO	29·68
MgO	20·41
Loss	45·46
Total	99·75
Sp. gr.	3·00

This dolomitic limestone might be useful as a blast furnace flux. It is only 6 miles north of Dhutra station on the B. N. Railway. The limestone along the river will be subject to flooding, and away from the river about 20 feet of overburden will need to be removed.

**Padampur* (21° 45′ : 83° 34′): Limestones and shales occur in the bed of the Mahanadi, between Launsara (21° 44′ : 83° 33′) and Tamdei (21° 43′ : 83° 35′), south of Padampur, and about 10 miles south of the nearest railway station, Jamga, B. N. Railway. They are faulted against sheared granite-gneiss with schistose inclusions, the fault consisting of a zone of silicified breccia with limonite and hematite impregnations, 100 to 200 feet wide, and striking roughly north-west and south-east. The limestones and shales are possibly of Cuddapah age. In the neighbourhood of Padampur they dip 30° north-east but are more disturbed at the contact of the fault. The beds strike across the river and presumably they extend several miles beyond. Within the stretch of river bed examined, there are four limestone horizons, their width of outcrop across the strike ranging from 50 feet to a maximum of about three furlongs. Shaly partings of green, purple or grey colour, are common. The limestones are fine-grained or compact and bluish grey in colour. The banks are usually covered by alluvium and there are no exposures away from the river.

On analyses limestones from three bands lying between Tamdei and Padampur were found to contain magnesia in excess as a consequence of which they cannot be used in cement industry. The fourth band, overlying the quartzites of Holsari Dungri near Launsara, consists of an argillaceous limestone which may be used in cement manufacture only after the addition of small quantities of pure limestone. The chief drawback is that the band can be worked only in the dry season as the place

* Originally recorded by Dr. B. C. Roy, Superintending Geologist, Geological Survey of India and subsequently re-examined by Mr. V. S. Krishnaswamy Assistant Geologist, Geological Survey of India.

where it occurs is liable to flooding during the monsoon. A sample of impure dolomitic limestone from the river bed was analysed in the Geological Survey laboratory and gave the following results:—

SiO_2	24·48
Al_2O_3	0·17
Fe_2O_3	0·39
CaO	21·28
MgO	15·20
Loss	33·54
Total	95·06
Sp. gr.	2·77

Bands of dolomitic limestone have been located near Bardarha (21° 46′ : 83° 31′), Nandopalli (21° 45′ : 83° 31′), Kusmul (21° 45′ : 83° 33′) and Gudum (21° 44′ : 83° 32′). Owing to the high percentage of magnesia these limestones can be used only for the manufacture of lime for building purposes.

**Lakhanpur* (21° 38′ : 83° 37′): About 8 miles S.S.E. of the Padampur area, occasional outcrops of limestones and shales in flat country covered by alluvium occur over an area of 6 miles long and 2 miles broad in the Lakhanpur valley. The underlying rocks are quartzites which, together with the limestones and shales, are folded in the form of an asymmetric pitching syncline, with a somewhat steeply dipping limb on the western side. There are several inconsistent bands of limestone between Lakhanpur, Darlipalli (21° 39′ : 83° 37′), Lelehar (21° 40′ : 83° 37′) and Paruabhadi (21° 40′ : 83° 38′). Around Lakhanpur the rocks seem to be flat lying, whereas around Chakramal (21° 38′ : 83° 39′), about a mile and a half north-east, they dip gently towards W.N.W. This suite of rocks is presumably a continuation of the beds at Padampur.

In the centre of the synclinal basin the limestone has been assumed to underlie an area of nearly one square mile and that for a minimum average thickness of 10 feet the quantity of limestone available will be of the order of 18 million tons. Analyses of two samples of limestone from this area show that the material is an argillaceous limestone containing less than 2% magnesia and can be used in cement manufacture after suitable blending with purer limestones. The limestones near Lelehar and Paruabhadi contain magnesia in excess and cannot be utilised in cement industry.

**Dungri* (21° 42′ : 83° 34′)—*Banjipali* (21° 38′ : 83° 30′): Extensive deposits of limestone occur in a strip of plain country 8 miles long and one mile broad around Dungri, Sauntmal, Badmal, Behera, Kusumda and Banjipali. Alluvium is thick in the area and rock exposures are found only in the small *nalas*. The limestones are very hard, usually fine grained and compact in texture. They carry thin veins of calcite and siderite and sometimes secondary silica. The limestones are whitish, bluish, purplish, greyish, greenish grey, light brown, reddish and pinkish in colour with intercalations of shales tinted likewise. These

* Originally recorded by Dr. B. C. Roy, Superintending Geologist, Geological Survey of India and subsequently re-examined by Mr. V. S. Krishnaswamy, Assistant Geologist, Geological Survey of India.

shaly intercalations vary in thickness from fractions of an inch to nearly one foot in places, but are commonly of smaller dimensions. Sometimes the shales are calcareous and show splintery or nodular structures. The calcareous shales pass gradually into limestones both along and across the strike.

The limestones and the associated shales are sandwiched between thick bands of quartzites and sandstones and occupy the limbs of an asymmetric anticline pitching towards N.N.W. In conformity with the nature of the folding, the limestones and shales dip 5°—10° towards north-west to W.N.W. and 15°—35° towards N.N.E. and north-east. In general, the thickness of the limestone horizon in any single section exposed in the *nalas* varies from a few feet to a maximum of 25-30 feet. At one place, however, a section of the horizon across the strike and taken along the Banjiharia *nala,* south of Badmal, shows a thickness of over 100 feet. This thickness, however, is likely to decrease gradually at depth.

In the absence of detailed prospecting it is not possible to determine the number of workable beds. Thorough prospecting and sampling at close intervals will be necessary for greater accuracy. The material could be conveniently brought to Dungri and thence to Padampur, which would involve crossing the Mahanadi river.

A number of limestone samples collected from typical bands around Dungri, Badmal and Banjipali were analysed in the Geological Survey laboratory and the results of three analyses are tabulated below:—

	Dungri.	Badmal.	Banjipali.
SiO_2	5·60	5·80	8·80
Al_2O_3	0·05	0·06	0·01
Fe_2O_3	0·71	0·80	0·39
CaO	49·84	49·84	48·44
MgO	0·39	1·15	0·72
Loss	39·90	40·74	38·92
Total ...	96·49	98·39	97·28
Sp. gr. ...	2·72	2·72	2·71

The above as well as the other analyses show that the percentage of magnesium carbonate is sufficiently low for the use of the limestones in cement manufacture. All the limestones carry some clayey matter which is, however, low in better grade limestones containing over 80% $CaCO_3$ and rather high in the inferior varieties where the $CaCO_3$ content varies between 70 to 80 per cent.

Putka (21° 10′ : 82° 58′): This small village, near Jagdalpur police-station, Bargarh subdivision, is on flat land with a couple of small *dungris* towards the north. Bedded limestones interbedded with quart-

zites and shales occur as scattered exposures in and around the village. The limestone is fine-grained and compact and on the weathered surface shows a greyish yellow colour usually with concentric rings. On freshly broken surfaces it is light bluish. The strike varies between N.N.W.-S.S.E. and N.N.E.-S.S.W., dipping vertically or at high angles both ways. The associated quartzites are usually much brecciated and show a network of chalcedony, flint, jasper and other secondary quartz. The width of the limestone beds varies from a few yards to 100 yards and one small ridge (1 furlong by half a furlong), just north-east of the village, is essentially composed of limestone. Around the village, the limestone could be intermittently traced for about a quarter of a mile along the strike. Similar limestones are said to occur around Nawapara (21° 09′ : 82° 57′) about 2 miles south-west of Putka, hence it occupies a considerable area. The average material is, however, a siliceous dolomite of little value except, perhaps, for the manufacture of lime. An average sample was analysed in the Geological Survey of India laboratory and gave the following results:—

SiO_2	8·10
Al_2O_3	0·06
Fe_2O_3	0·82
CaO	26·88
MgO	20·04
Loss	43·30
Total	99·20
Sp. gr.	2·86

Future

The deposits of limestone in Koraput are rather inaccessible. The Kottametta deposit is about 18 miles from Malkanagiri and 82 miles from Jeypore, by road. It is also about 50 miles along the Sabari river from Motu, from where the river is navigable *via* the Godavari to Rajahmundry and Cocanada. Along the latter route it would be necessary to clear the river bed between Kottametta and Motu. Hence, there does not appear to be any likelihood for the appearance of an extensive cement industry from these deposits, but, as the Jeypore plateau develops, the manufacture of cement in a small way may become possible. The difficulty for a local industry would be fuel, unless electric kilns could be installed.

Near the Mahanadi river, in Sambalpur, the possibilities of developing a cement industry are much more favourable, for here, not only are some of the deposits reasonably close to the main B. N. Railway, but also coal of sufficiently good quality is available. These deposits, also, may find a market as flux in the iron and steel industry. They

all suffer from one drawback, however, and that is the liability of the quarries in the plain country to flooding during the monsoon.

The impure dolomitic limestone deposits of Bargarh are unlikely to give rise to any industry in the future.

CHAPTER XVIII

MANGANESE

General

India is one of the largest producers of manganese-ore in the world being second only to Russia, and it is probable that exports of high-grade ore actually exceed those from Russia. Most of this ore in India is mined in the Central Provinces. Although unimportant occurrences of manganese minerals have been recorded in Orissa it is only recently that any workable deposits have been found. During recent work by the Geological Survey of India, excellent deposits of high grade ore were examined at Kutingi (19° 05′ : 83° 10′), a place readily accessible by road to Rayagada station on the B.-N. Railway, which is only 117 miles from Vizagapatam.

Uses

There is a steady consumption of manganese-ore in India at the works of the iron and steel companies. Not only is it added to the blast furnace in the manufacture of pig-iron and to the open-hearth furnace in the production of steel, but also it is used in the manufacture of ferromanganese. As a rule lower grade ore is used in the blast furnace and high grade ore used in the open-hearth furnace. For the manufacture of ferromanganese it is desirable to utilise high grade ore low in phosphorus.

Manganese-ores are also used in chemical industries as oxidising agents. Here, the manganese content of the ore is often not so important as the available oxygen, which is usually expressed in terms of the percentage of manganese-peroxide, MnO_2. Impurities soluble in acid are deleterious, and for the glass industry the ore must be as free as possible from iron. Such ores usually contain over 80 per cent MnO_2.

A particularly pure variety of chemical ore is used in the manufacture of dry cells; it is not quite clear what is the best type of ore for this purpose, as within limits the amount of MnO_2 in the ore does not appear to affect the suitability. Presumably the physical condition of the MnO_2—that is, the mineral constituents in which it occurs—is the important factor. High grade manganese-ores whenever found should be tested for this purpose.

Grading

Many iron-ores contain manganese, and indeed there is every gradation from iron-ores to manganese-ores. The following classification is adopted for such ores:—

Manganese-ore—35 per cent Mn and over

Ferruginous manganese-ore—10 to 35 per cent Mn.

Manganiferous iron-ore—5 to 10 per cent Mn.

Normally, in India, manganese-ore is graded as follows:—

First grade ore—over 48 per cent Mn.

Second grade ore—between 45 and 48 per cent Mn.

Third grade ore—below 45 per cent Mn.

In Bihar, however, this grading is not used. All ore below 48 per cent manganese is either sold as second grade, even down to 38 per cent, or the ore is simply sold on its analysis. Chemical ore, sold as "peroxide", may reach as high as 58-59 per cent manganese. Some ores, down to 32 per cent Mn with as much as 17 per cent iron, are sold as manganese iron-ores to the iron and steel industry.

Ganjam

(G. C. Chaterji)

Manganese minerals are found associated with the garnet-gneisses (khondalite) in many places, usually as stains, irregular disseminations, or small veins in the body of the country rock. On the weathered surfaces of many of the khondalites, black metallic coatings of manganese are often seen. In certain places, e.g., near Boirani (19° 35′ : 84° 45′), veins of manganese minerals replace the garnet-gneiss.

A systematic geological survey of the regions which were suggested as promising by L. L. Fermor (*Mem. G. S. I.*, Vol. XXXVII, pt. IV, page 1033) has been started, and the area between Chadiapalli (19° 38′ : 84° 15′), Boirani, (19° 35′ : 84° 45′). Purushottapur (19° 31′ : 84° 53′), Budhamb (19° 37′ : 84° 52′), Kodala (19° 37′ : 84° 56′), Kanchana (19° 37′ : 84° 59′) and Boroda (19° 26′ : 85° 00′), has so far been mapped, but no workable deposit has been found to date. However, as good deposits of manganese-ore exist in similar geological formations in the adjoining districts of Vizagapatam and Koraput it is probable that some may be located during thorough mapping of this district.

About three-quarters of a mile south-east of village Boirani (19° 35′ : 84° 45′) a manganese-bearing vein cuts garnet-felspar rock. The maximum thickness of the mineralised vein is about 4 feet, but the ore material occurs as lenticular pockets, and much felspar is mixed with it. The deposit is, therefore, not of economic interest.

Further east, near Gudiali (19° 34′ : 84° 47′), some small manganese-bearing veinlets in the rock exposures yield, on weathering, nodules of manganese minerals which collect at the foot of the hills.

Between Khallikota (19° 36′ : 85° 05′) and Rambha (19° 31′ : 85° 05′), disseminated manganese minerals occur in garnet-gneisses, but no workable ore-body has been found.

About half a mile south-east of Gollapada (19° 57′ : 84° 37′) and 3 miles north-east of Russelkonda (19° 55′ : 84° 35′), some small pockets of manganese minerals have been found in garnet-gneisses on a hill. On weathering out, the ore collects at the foot of the hill with other debris.

Koraput

(A. M. N. Ghosh)

The presence of manganese in Koraput district was not known until 1938, when an employee of the Jeypore Zemindary came across small outcrops of manganese-ore at Kutingi. Excavations and trial pits were then made in order to trace any likely large deposit.

In January, 1940, during the mineral examination made by the Geological Survey, the main ore-body was discovered after making a few excavations at favourable places. At the same time four new deposits were proved. One was already exposed as a result of weathering and was being worked by a local contractor.

Several minor deposits have also been discovered.

Kutingi (19° 05′ : 83° 10′)

Kutingi is a small village immediately on the western side of the new motor road connecting Rayagada (19° 10′ : 83° 25′) and Koraput (18° 49′ : 82° 43′), and is 45 miles from Koraput and 23 miles from Rayagada on the B. N. Railway between Vizianagram and Raipur. The deposits occur to the N.N.W. and S.S.W. of the village, along a narrow belt nearly a mile and a half long, but are not continuous throughout this length.

Geology—The country rock in the neighbourhood of the manganese deposits consists of garnet, sillimanite and quartz (khondalite); the prevailing strike is N.N.E.-S.S.W., although locally the strike is N.E.-S.W. As a result of isoclinal folding the dip of the rocks is invariably easterly from 30° to 50°. Specks and thin streaks of graphite are occasionally noticed in the khondalite.

Masses of quartzite, sometimes garnetiferous, are apparently interbanded with the khondalite and these quartzites, although thin, can be traced over relatively long distances. The khondalite is also traversed by veins of quartz and of pegmatite and in the proximity of granite it has been granitised. In such cases the granite contains numerous red garnets apparently derived from the khondalite. Near Kutingi, the granite is exposed mostly in the river beds and valleys. The deposits of manganese-ore occur along the western edge of the zone of contact of the granite and the khondalite, and are intimately associated with a dark chocolate-coloured quartzose rock. This forms a bed in the khondalite which, near the manganese, is commonly converted into lithomarge. Pebbles of banded jasper may be noticed on the hillocks containing manganese-ore.

Ore deposits—The manganese-ore occurs in the form of bands and lenses in the khondalite suite and is traversed by veins of quartz and felspar. Although to a great extent it is rather impure, containing fine grains of quartz from its close association with the quartzose rock, large masses of the purer ore, mostly psilomelane, do occur. Both on the sides as well as along the summits of the low ridges, 100 to 150 feet above their base, the ore appears as huge boulders of higher grade. The hump-shaped hillocks containing the ore occur at the foot of the main khondalite scarps further west, and stretch in a roughly N.-S. direction.

The ore is frequently stained with limonite, and the larger blocks are spongy and cavernous. Sometimes the structure of the ore is kidney-shaped, mamillary and botryoidal.

Although most of the ore appears to be of psilomelane, it also contains wad and thin streaks and narrow bands of a black powdery mineral, probably pyrolusite. The former has a dull metallic lustre and the latter a steel grey to bluish grey colour. The bulk of the ore, as exposed at the surface, seems second and third grade material but some first grade ore has been obtained. There is every likelihood that the quality will improve in depth. In a few cases shining crystals of braunite were noticed. The specific gravity of ten samples shows an average of 4·2, the highest being 4·51.

Deposit No. 1—This deposit, about one mile S.S.W. of Kutingi, occurs on a hummock at the base of the khondalite scarp. The maximum height of the hummock is about 150 feet. This is also of khondalite and associated rocks, and the eastern portion has a capping of laterite, which, however, does not continue westwards to the crest. Scattered blocks and boulders of manganese ore of all sizes occur almost continuously along the summit of the ridge in a north-south direction for a distance of nearly 1,550 feet. The actual length of outcrop exposed at the surface is nearly 1,200 feet, and the maximum and minimum widths of the exposures are 50 and 15 feet respectively. Both on the northern and the southern slopes the altered manganese-bearing rocks and the ore occur *in situ* and appear within a few feet of the base of the ridge, suggesting continuity of the latter to depths of 75 to 100 feet. The ore, mostly psilomelane with a little pyrolusite and wad, consists of moderately good material as judged from the outcrops. A picked specimen, analysed in the Geological Survey of India laboratory, yielded the following results:—

Manganese	..	...	...	51·35 per cent.
Iron	...	...	...	2·23 " "
Insoluble matter		...	...	5·87 " "
P_2O_5	...	...	...	*Nil.*

This is first grade ore suitable for metallurgical purpose.

Assuming an average depth of 75 feet, width 30 feet, and length 1,200 feet, about 270,000 tons of ore may be expected. For the purpose of calculation 10 c.ft. of the solid ore has been taken to weigh one ton.

Between the main manganese band on the top of the hill and the capping of laterite on its eastern side, a large area of the hill-slope supports float ore. Material collected at one place from an area 10 feet by 10 feet, was stacked and one c. ft. of ore obtained.

Deposit No. 2—In this deposit, a little over ½ mile south-west of Kutingi, the manganese-ore also occurs on a low ridge, which is really the continuation northwards of No. 1 hill, a small stream dividing the two. Although manganese-ore does not occur in the bed of the stream, it is present along the axis of elongation of the ridge as an almost continuous band and was found to continue right up to the southern extremity of the hillock as far as the base of the ridge. The relative height of the summit of the hillock from the base is about 80 feet. Manganiferous rock is also present at the northern edge of the same ridge. The run of the ore-body is N.N.E.-S.S.W., although locally the strike varies between north-south and N.10°E.—S.10°W. The dip of the ore is up to 60° in places, and is towards the east.

The total length of exposed ore, much of it broken up and rugged owing to weathering, is 500 feet. The width at the southern end is 50 feet and at the northern end 16 feet. An average depth of 50 feet and a width of 20 feet have been assumed. The amount of ore is 500,000 c.ft. or 50,000 tons.

The main line of ore extends, although considerably attenuated northwards beyond the footpath from Kutingi to Khalkona (19° 03′ : 83° 09′) and was traced over a length of 60 feet.

Trenching along the north-eastern foot of No. 2 hill revealed the presence of another band of manganese-ore. The area excavated was 10 feet by 6 feet, and solid ore was struck at a depth of two feet from the surface. This band is likely to continue into the hill in a southerly direction.

A stray sample of third-grade ore collected from the hilltop was found on analysis to contain 40·26 per cent manganese.

Deposit No. 3.—About 600 yards S.S.W. of Kutingi there are two bands of high-grade ore. The eastern one, some 13 to 15 feet thick, was discovered in 1938. Jungle clearing and trenching led to the discovery of the second, some 45 feet thick, a few yards to the west. The western band disappears northwards into the hill, and is likely to continue.

The run of the eastern band is N.10°W.—S.10°E.; it forms the eastern limb of an isoclinal fold, the crest of which is removed by denudation and the western limb of which is represented by the 45-foot western band. The eastern limb is exposed for a length of 200 feet and crops out about 15 feet above the base of the hill. The ore in sight is 200 feet by 15 feet by 15 feet=45,000 c.ft., or 4,500 tons, some of which appears to be first-grade.

It is not possible, at present, to form any idea of the western ore-body which also contains high-grade ore.

It should be noted that Nos. 1, 2 and 3 deposits are practically continuous over a distance of nearly ¾ mile and further excavations in Nos. 2 and 3 hills will very likely expose more of the second band.

Five samples were analysed and yielded the following results:—

	Manganese per cent	Iron per cent	Insol. per cent	P_2O_5 per cent
Sample H. .	51·35	5·02	3·30	*Nil.*
" G ...	53·52	3·91	1·86	0·02
" E ...	55·42	1·12	7·08	0·01
" D .	49·72	—	—	—
" A .	44·34	—	—	—

Samples H, G, D and E are first-grade ore with low phosphorus content. Sample E appears to be a good chemical ore. Sample A is of third-grade ore. Complete analyses were not made.

Deposit No. 4—About half a mile north-west of Kutingi a deposit is isolated on a dome-shaped hillock elongated along a N.N.E.-S.S.W. direction and rising to over 100 feet. The deposit contains some high-grade ore, and is associated with khondalite, but the rock immediately underlying the ore is a quartzite dipping at a high angle in an E.S.E. direction. The deposit appears to be lenticular since it could not be traced on the southern side of the ridge, although it is present at the northern end. Trenches and trial pits were made.

The deposit is over 500 feet long and its maximum and minimum widths are 40 and 10 feet respectively. The strike of the exposure is N.N.E. The ore continues to the base of the hill on the northern side, suggesting persistence in depth. Assuming a depth of 70 feet and an average width of 25 feet the minimum amount of ore is 875,000 c.ft. or 87,500 tons.

Three samples from this deposit were analysed. Two proved to be third-grade ore containing 45·48 per cent and 44·98 per cent of manganese. The third is first-grade:—

Manganese	54·60 per cent.
Iron	1·12 " "
Insol.	10·00 " "
P_2O_5	0·06 " "

Deposit No. 5.—This is really the northerly continuation of No. 4 deposit, from which it is separated by a small hill stream. The length of the outcrop is 135 feet, and breadth 8—10 feet. The depth is likely to be 20—30 feet.

Assuming that the individual deposits are constant in depth and thickness, Nos. 1 to 4 deposits are likely to contain 392,000 tons; including float and minor bands, some 400,000 tons of manganese-ore of various grades are available above the base of the hills. How much marketable ore can be extracted may be determined by trenching and sampling by future prospecting. The figures given are merely intended

to convey an idea of the approximate size of the deposits and are by no means final.

Regarding the quality of ore it was not intended to systematically prospect the deposits after they had been opened up during this investigation. The analyses, although made from representative samples each form a wide area, may not prove entirely representative of the ore-bodies. Large blocks of the ore were collected from different parts of each individual band, broken up and quartered in the field, and one or two pieces picked out from each lot. In doing so the best pieces may have been unconsciously picked, although the results of analyses show that this was not always the case. The lowest figure of 40·26 per cent Mn and the highest 55·42 per cent Mn show the wide variation of the manganese content of these ores.

As the deposits occur on low hillocks, 50 to 100 feet high, they may be easily quarried. The rocks are soft and decomposed. Little or no pumping will be necessary in quarrying. The overburden to be removed in the initial stages is almost negligible, and no extensive machinery will be required. The deposits lie within a furlong of an all-weather motor road and there should be no difficulty in transporting the ore to Rayagada, the nearest railway station, which is only 23 miles from the deposits. The distance from Rayagada to Vizagapatam, from which port much of the Central Provinces ores are exported, is 117 miles.

Labour may have to be brought from the neighbouring States, or from Vizagapatam district, as the local people have not yet learnt the use of pick and shovel. The cost of imported labour ranged between annas four to annas six per man per day in 1940-41 but is likely to be much higher at present.

Other deposits

Damanaguda (19° 05′ . 83° 11′) and *Lohara Kuttili* (19° 06′ : 83° 11′): Pebbles of psilomelane were noticed at several places in the ploughed fields two miles north of Kutingi, and about half a mile south-east of Damanaguda and again near Lohara Kuttili. About half a mile north of the latter village a thin outcrop of chocolate-coloured manganiferous rock was noticed on a ridge at the foot of the main scarp. It appears, therefore, that the belt of manganese-bearing rock, although discontinuous, is nearly four miles long, and extends still further.

Manganese-ore discovered by Mr. K. Satyanarayana of the Jeypore Board High School on the hill 2252, immediately to the north of Kuttili (19° 07′ : 83° 12′) near the main road to Rayagada (19° 10′ : 83° 25′) occurs as thin bands and layers in decomposed khondalite and lithomarge. The ore extends for a distance of about 150 feet with a maximum width of 8 feet, but according to Dr. Dey appears to be of low grade. An analysis of a selected specimen showed 45·15 per cent Mn.

**Pullabadi* (19° 09′ : 83° 13′): About a furlong north-west and north of the village there are small occurrences of second-grade manganese-ore, consisting chiefly of psilomelane and a small amount of pyrolusite, in decomposed khondalite. A picked specimen gave 46% Mn on analysis.

* Recorded by Mr. Muktinath.

**Barijolla* (19° 11′ : 83° 23′): Thin layers and lenses of poor quality manganese-ore are present on a small hill about a furlong north of the village. The ore is associated with quartzite near its junction with calciphyre. Wad occurs at the eastern foot of the same hill.

**Bariguda* (19° 30′ : 83° 27′): About 100 yards N.N.W. of the village a highly siliceous and poor quality manganese-ore with some wad occurs in association with calciphyre.

Muniguda (19° 38′ : 83° 29′): An outcrop of manganese-ore, measuring about 80 feet in length and 15 feet in width, was found in the graphite and garnetiferous schists on the Raipur road, immediately alongside the railway, about 2 miles N.N.W. of Muniguda railway station. The ore, according to Dr. Dey, is of low grade. One analysis showed 38·44 per cent Mn.

Pathar Dongar (19° 47′ : 83° 28′): About 8½ miles further north, near milestone 79/6, the road-cutting exposes layers and veins of manganese-ore in the form of psilomelane and wad, in the altered gneisses and schists cropping out on the southern end of Pathar Dongar. The locality is within a mile of the railway line but, so far as Dr. Dey could judge from the surface exposures, the total quantity of marketable ore appears to be extremely small. A sample on analysis yielded only 26·41 per cent Mn.

Kotandoravalasa (18° 29′ : 85° 54′): Traces of manganese-ore in the form of nodules and lenses are found associated with decomposed khondalite on the S. W. slope of hill 3661 near Kotandoravalasa, Pottangi taluk.

Santemra (19° 38′ : 82° 32′): Some manganese-ore was found on the top of a low hillock, about 2½ miles south-east of Santemra. The ore consists of low-grade psilomelane and pyrolusite associated with limonite, and has been formed by lateritic weathering of ferruginous slates and shales. The deposit is not sufficiently large to warrant exploitation. The manganese-ore is capriciously distributed in the laterite, which is 50 feet thick.

Tittiveru (18° 22′ : 81° 46′): While investigating the limestone occurrences in Malakanagiri Dr. Dey came across small lumps and veins of manganese oxide in conjunction with hematite along a fault-rock occurring on a low hill about half a mile W.S.W. of Tittiveru.

Small deposits of manganese have recently been reported near Amdodala (19° 50′ : 83° 28′), Mandhara (19° 03′ : 83° 12′) and Rayagada station.

†*Devudala* (19° 14′ : 83° 24′): On a small hill, about half a mile W.N.W. of the village, insignificant stringers and lenticles of manganese-ore are present in brecciated quartzite striking N-S.

†*Devajolla* (19° 02′ : 83° 12′): A deposit of manganese-ore associated with some hematite and limonite was found in a sheared quartzitic rock north-west of Devajolla. The deposit was traced for nearly two furlongs along its strike and the results obtained were sufficiently encouraging

* Recorded by Mr. Muktinath.

† Recorded by Mr. S. C. Chakravarty, Assistant Geologist, Geological Survey of India.

to warrant investigation in greater detail. A picked specimen was partially analysed and gave MnO_2—45·94% and P_2O_5—0·59%.

Future

The Kutingi deposit will undoubtedly be developed in the near future. In consequence of its accessibility to the seaboard it can readily compete for export with deposits situated elsewhere in India.

For the province to obtain the maximum value from such deposits as this, every possible way in which the ore could be utilised for local industry should be investigated. The highest grade ore should be tested for use in dry batteries, or for use in chemical industries and in glass-melting. It is doubtful whether ferromanganese could be successfully made locally, but the possibility of erecting a small furnace, using charcoal as fuel, for making low phosphorus ferromanganese, may repay investigation.

CHAPTER XIX

MICA

General

India is the world's largest producer of the better grades and larger sizes of mica. Most of this mica is mined in Bihar, but large amounts of poorer quality are obtained from Rajputana and Madras. Attempts have been made to mine mica in Orissa, but so far without success, as the quality has been too poor for mining to be payable. These attempts have been confined mainly to Sambalpur district, but there has been a certain amount of prospecting in Ganjam and Angul.

Uses

Mica is the name applied to a group of alumina silicates of potash, iron, magnesia, etc. The mica occurring in pegmatites in Orissa is the potash mica known as muscovite. Its most striking property is the ease with which it can be split along the cleavage planes into extremely thin films. It is also transparent and colourless in thin sheets, resilient and tough, chemically very stable, resistant to high temperature and a non-conductor of heat and electricity.

Its remarkable insulating properties make mica invaluable to the electrical industry. It is used for insulating commutator segments, in electric heaters, rheostats, electric condensers, fuse boxes, lamp sockets, sparking plugs, as washers, etc. Small thin films or splittings cemented together are built up into sheets and sold as *micanite*. Being unaffected by moderately high temperature the larger sizes of mica are also used for stove and furnace windows, gas lamp chimneys and shades, etc.

Ground mica, made from waste, is used in the manufacture of patent roofing, wall paper, automobile tyres, moulded insulators, as a filler in rubber goods, etc., and for fancy paints, and lubrication.

Marketing

Muscovite is of various colours, green, brown, white, silver and ruby. The most valuable is that known as "ruby mica" to which class most of the production in the Bihar mica belt belongs. Sheets of this mica over about one-eighth inch in thickness have a beautiful ruby colour the depth of which increases with thickness.

After the crude-mica from the mine has been cut and flaws removed it is known as "block mica", the thickness of which may vary down to ·008 inch. The average percentage of block mica produced from crude mica in Bihar is not definitely known, but it is probably between 20 and 25 per cent for the belt as a whole.

Block mica is sorted according to size and quality. The various qualities are described as follows:—

Superfine
Clear
Slightly stained
Fair stained
Good stained
Stained
Heavily stained
Badly stained
Densely stained
Black spotted

These qualities are, unfortunately, not standardised. Different sorters and firms have their own interpretation of individual quality and, in addition, selling competition gives rise to variation. In order to remove these difficulties, sets of carefully prepared standards are now available from the Geological Survey of India for Rs. 50. On the whole, there is an approximately consistent local standard which might be referred to as the "bazar market standard".

The following grading according to size is used:—

Special	. .. .	48	to 64	sq. inches
A-1	. .. ...	36	to 48	" "
No. 1	... .	24	to 36	" "
No. 2	. ...	15	to 24	" "
No. 3	... .	10	to 15	" "
No. 4	.. ..	6	to 10	" "
No. 5	... .	3	to 6	" "
No. 5½	... ...	2½	to 3	" "
No. 6	... ...	1	to 2½	" "
No. 7	... ...	Below	1	sq. inch

The greater part of all sizes of high quality mica is exported as block mica. Of the low quality mica all sizes No. 4 and up are exported as block mica, but the greater part of No. 5 and down is split into

extremely thin laminae which are known as "splittings" (approximately ·001 inch in thickness). However, a certain small proportion of these small sizes, depending on the market requirement, is exported as block. From the high quality block mica a steadily increasing amount is being split into condenser films in India.

The prices obtained depend on quality and size, and for each grade the price will vary widely from time to time according to the demand. For special sizes superfine, prices as high as Rs. 2,000 to Rs. 3,000 per maund are obtained, but the total quantity of such mica produced per year amounts to only a few maunds. The industry depends for its stability rather on the large production of low quality mica of all sizes. The average price range for all qualities and sizes of block mica was between Rs. 60 and Rs. 130 per maund in 1941-42.

Balasore

(A. K. Dey)

Baghudi (21° 20′ : 86° 40′): This village is about four miles N.N.W. of Soro railway station. The rocks here are garnetiferous gneisses accompanied by basic rocks, and are traversed by pegmatite veins. From a decomposed pegmatite near a road-metal quarry, within 40 yards of the road, between milestones 3 and 4 and about a furlong north-east of Baghudi village, small books of decomposed dark coloured and somewhat strained mica up to 1½ inches in diameter were obtained. An excavation was carried to a depth of 7 feet without encouraging results.

Cuttack

(A. K. Dey)

In Cuttack mica has been found in the pegmatites cutting gneisses and schists at Chatia (20° 37′ : 86° 04′), Kadalibadi (20° 29′ : 85° 36′), Krushnopur (20° 28′ : 85° 34′), Kumusar (20° 19′ : 85° 29′), Brahmapur, (20° 20′ : 85° 28′), Parsurampur (20° 17′ : 85° 22′), Madhuapali (20° 17′ : 85° 23′) and Baideswar (20° 21′ : 85° 23′). At all of these localities mica is either too small in size or too poor in quality to be of value.

In Angul mica is found in the pegmatites which occur as veins and lenticular masses intrusive in the gneisses at Burhapanka (20° 52′ : 84° 14′), Girang (20° 51′ : 85° 10′), Nanguliabera (20° 48′ : 85° 11′) and Basala (25° 44′ : 85° 06′). The mica books measure up to 6 inches in diameter, but are either much strained or spotted. An attempt to work the deposits proved unsuccessful as good mica is deficient.

Chatia (20° 37′ : 86° 04′): The village is about 2½ miles from Byree railway station. West of the village, about a furlong E.N.E. of Amrabati, small pieces of mica were found scattered around a small tank. No pegmatite was seen to crop out in the neighbourhood, but it is believed that a vein was excavated whilst making the tank. The specimens were very small in size, rarely exceeding one inch across. The locality, therefore, does not offer any attraction for further investigation.

Kadalibadi (20° 29′ : 85° 36′): About 14 miles from Raj Athgarh, in a field north-west of Malbeharpur, a village west of Kadalibadi, small pieces of mica were seen associated with quartz debris. Some clear specimens of mica measuring up to one inch across were obtained from a pegmatite, but within a depth of 4½ feet from the surface the mica became heavily stained and sheared.

About a furlong N.N.W. of this locality mica was found in a pegmatite vein exposed in a field but excavation yielded no encouraging results.

Krushnopur (20° 28′ : 85° 34′): Small silvery flakes of mica were found scattered on the surface of a paddy field S.S.W. of this village about 16 miles from Raj Athgarh. Some specimens of clear but rather strained mica, measuring up to 2 inches by 3 inches in size, were obtained from a pegmatite about 2½ feet below the surface but beyond this depth the mica diminished in size, and at a depth of 5 feet from the surface specimens rarely measured more than one inch across and were all strained.

Kumusar (20° 19′ : 85° 29′): About 28 miles from Khurda Road railway station, just within the reserved forest about half a mile E.S.E. of this village, a small mica-bearing pegmatite is exposed. On opening up, some flakes of mica measuring 3 inches by 3 inches were obtained but these were a dark coloured biotitic variety and of little value.

**Brahmapur* (20° 20′ : 85° 28′): In the course of shallow, *uparchalla* prospecting for mica a mica-bearing pegmatite was noticed in a paddy field about one mile south-east of the village, which lies nearly 27 miles from Khurda Road station. The country rock traversed by the pegmatite consists of garnetiferous gneiss. The pegmatite dips eastwards at an angle of 30° and has a 2-foot core of massive quartz both sides of which are bounded by a mica-bearing zone composed of quartz, felspar and mica. The footwall of the pegmatite is two feet thick and is richer in mica than the hanging wall the thickness of which is one foot. The total thickness of the pegmatite is 5 feet. The mica met with is of ruby colour and is somewhat stained. The felspars are pink and white in colour. Biotite is present especially near the contact of the pegmatite with the country rock. A trial pit was made up to a depth of ten feet and books of muscovite measuring up to 4″ across and 1½″ thick were taken out with the help of untrained local labour. The mica is badly sheared in the upper parts of the pegmatite.

Parsurampur (20° 17′ : 85° 22′): About 26 miles from Khurda Road station, a mica-bearing pegmatite exposed at the corner of a paddy field along the roadside about two furlongs north-west of this village, was prospected by a shallow cut but the mica measured less than one inch in size.

About a furlong further north, in a pegmatite vein cropping out along the edge of a dry reservoir a prospecting pit disclosed only small flakes of biotite. Similar mica was seen on the edge of a cultivated field immediately north-west of the village.

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*Recorded by Mr. G. C. Chatterjee.

Madhuapali (20° 17′ : 85° 23′): Pieces of mica found scattered with felspar debris on the sides of the *Khasmahal* tank, north-west of this village, about 25 miles from Khurda Road station, are presumably from a pegmatite exposed whilst excavating the tank. The bottom of the tank is under water, but the specimens in the debris were of much decomposed and sheared biotite.

Baideswar (20° 21′ : 85° 23′): About 30 miles from Khurda Road station a small pegmatite vein, exposed in a *nala* about half a furlong S.S.W. of the Inspection Bungalow, yielded, on excavation, small flakes of mica rarely more than three quarters of an inch across.

The pegmatite vein seen cutting the garnetiferous gneisses and schists on the western side of the Baideswar hill, a little above its base, was opened up at one place and only dark coloured biotitic mica measuring up to one inch in diameter was found. Other minerals occurring in the pegmatite include tourmaline, felspar and beryl.

Burhapanka (20° 52′ : 84° 14′): At this village, four or five miles from Meramandeli railway station, mica-bearing pegmatites occur as small veins and lenses cutting the garnetiferous muscovite-biotite-gneisses. By the roadside, between milestones 8 and 9, about half a mile south of Apratipur village, a trench measuring about 100 feet in length, 45 feet in width, and probably 20 feet in depth, and which is now under water, represents the work on one vein. It is reported that mica books measuring one foot across were obtained and pieces of mica measuring up to 2 inches by 4 inches were seen, but the quality is very poor. There are also four prospecting pits close by, but these are now filled with debris.

In the paddy fields about 1½ miles east of the trench mentioned above, and close to Dhenkanal State border, mica was prospected in four shallow diggings: three together, and a fourth about 100 yards to the north-east. The mica exposed in the diggings is of small size and of poor quality.

Girang (20° 51′ : 85° 10′): Near the Angul-Meramandeli road, about 10 miles from the Meramandeli station, mica is found in north-east trending pegmatite veins cutting garnetiferous gneisses locally containing bands of hornblende schists. These pegmatite veins are of varying size and persistency, and range in composition from mica-felspar-pegmatite to quartz veins containing small flakes of mica. Biotite is seen in trifling quantities and occasionally tourmaline.

A little to the north of the 4th milestone, about one mile south of Girang, outcrops of pegmatite are seen at intervals striking in a N.N.E. direction for a distance of about half a mile. One of these has been explored by a trench, 200 feet in length and 55 feet in width and which is now full of water. The pegmatite is about 20 feet in width and, at the surface, books of mica measuring up to 2 by 3 inches may be seen, but they are usually strained and spotted.

*During World War II Messrs. Gour Gopal Das and Kashi Nath Das of Cuttack took a mining lease of the area and attempted to reopen the

* Recorded by Dr. A. G. Jhingran.

pits. A small amount of mica was raised which was sent for examination to the Government Inspector of Mica who reported as follows:

> "One sample of brownish muscovite roughly sickle-dressed, mostly No. 5½ and No. 6 grade. There are a few pieces of No. 5. About 50% of the sample stained and good stained quality, the balance being lightly specked with black inclusions."

*Owing to financial difficulties the lessees were not able to undertake explorations on a large scale and work was abandoned. The pit that was examined was not promising and the figures for output indicate that prospects are meagre for obtaining large quantities of mica from this place.

Open cuts made on the other outcrops of pegmatite in this locality have not yielded an encouraging result. Further west across the newly made unmetalled road, there are more veins of mica-bearing pegmatites, but the mica is small. To the east of the village the mica-bearing pegmatites have been prospected by means of shallow open-cuts, but the mica is either two small in size or too poor in quality to be of value.

Nanguliabera (20° 48′ : 85° 11′): This village is about 12½ miles from Meramandeli railway station, *via* Girang. The principal mica-bearing pegmatite occurs in garnetiferous gneisses of the khondalite suite about half a mile to the north-west and exposed to the north-east and south-east of a tank. The strike is N.N.E. and the vein consists of mica, felspar and quartz. Occasionally a little beryl may be seen. The exposures at the north-eastern end of the tank have been prospected along the strike by a trench 300 feet by 8 feet by 6 feet. The width of the pegmatite is about 12 feet. The specimens of mica at the outcrops are usually very small, highly flawed and spotted. The largest specimen obtained measured 6 inches by 2 inches. About quarter of a mile to the N.N.E. another pegmatite has been prospected by a shallow open-cut but the mica exposed is too small to be of value. About a furlong south of the tank a quartz vein containing small flakes of mica is seen.

Basala (20° 44′ : 85° 06′): At this roadside village, 25 miles from Meramandeli railway station, mica pegmatites have been investigated by a large trench and several pits and open-cuts. The pegmatites strike N.N.E. and they vary in width and persistency. Just east of the village, on the path leading to a tank, a mica-bearing pegmatite is exposed. Excavations are now filled but, in the debris, mica measuring 2 by 2 inches was found, all badly stained and strained. Similar mica was found in a shallow digging north-east of Dhanunjaipur, a village adjacent to Basala. About half a mile north-west of Basala, along the right bank of Bauli Nadi, five prospecting pits have been sunk on a pegmatite vein striking N.20° E. The pegmatite consists of tourmaline, mica, felspar and quartz, and grades to quartz containing local segregations of mica; in places the quartz is rose-coloured. The mica, as exposed in the excavations, is sheared and spotted, the largest books measured 3½ inches by 2½ inches.

Two miles E.S.E. of Basala and about half a mile north of the road near where it crosses the Hindol State boundary, pegmatites have been investigated by a large trench and four shallow diggings. The trench

* **Recorded by Dr. A. G. Jhingran.**

measures 200 feet in length, 30 feet in width and about 20 feet in depth and strikes in a N.N.E. direction. The pegmatite as exposed is between 14 to 16 feet wide and consists of mica, felspar and quartz. The bottom of the trench was under water, but it is reported by the people who worked there that books of mica measuring one foot across were obtained. The mica now visible is of small size and of poor quality. S.S.W. of the trench, there are four small open-cuts in the pegmatite vein but they do not offer any indication of the presence of mica of commercial value.

Ganjam

(G. C. Chaterji)

Although mica-bearing pegmatites have been found in all the sub-divisions of Ganjam, none contain mica sufficiently attractive to be worked at present. In a few cases the quality is good but the sizes are not large enough for the deposits to be payable. Pegmatites are more particularly abundant in Ghumsar; the majority occur in granitic gneisses.

Juikholo (20° 14′ : 84° 28′): Just inside the reserved forest, about three quarters of a mile north-west of the village, a pegmatite is exposed in a nullah and contains stained and ruled ruby mica, the books averaging 3 inches across. Down to 4 feet below the surface the quality did not change. The pegmatite has no quartz core and is composed of felspar and muscovite.

Dundurgochha (20° 15′ : 84° 27′): Just south of the village a pegmatite strikes approximately east-west and contains heavily stained ruby mica. The maximum size obtained from a shallow prospecting pit about 3 feet deep is 6 inches by 4 inches. The pegmatite has no quartz core exposed.

Nediguda (20° 11′ : 84° 34′): About a quarter of a mile to the south-east of this village, on the edge of a cultivated field, a pegmatite strikes N.W.-S.E. The vein is one foot wide, and a prospecting pit about 3 feet deep exposed densely stained white mica in a white-felspar zone bordering a quartz core. The quality may improve in depth. The mica books are about 3 inches to 4 inches across, a few are larger. The country rock of the area is a white coloured fine-banded gneiss consisting essentially of quartz, felspar and garnet with some biotite.

Dwaragam (19° 20′ : 84° 32′): About 1½ furlongs south-east of the village a mica-bearing pegmatite crops out for about 150 feet at the northern foot of the small hillock called Bhaludhimira. The pegmatite is irregular in shape and has sent out apophyses into the country rock consisting of garnetiferous granitic-gneiss. At its eastern end the pegmatite strikes approximately E.N.E.-W.S.W. and almost east-west at its western end where it passes into graphic-granite composed of white and pink felspars, quartz and some small flakes of bronze coloured biotite. The eastern end of the mica-bearing zone of the pegmatite consists of kaolinised felspar, quartz and muscovite with a little garnet and biotite. The pegmatite has no quartz core nor does it carry tourmaline or other rare minerals.

Tested to depths up to a maximum of 8 feet by means of prospecting pits and trenches, the pegmatite yielded crushed books of muscovite measuring 10″ × 6″ × 1½″, but being badly cracked blocks of sound mica

larger than 3" to 4" across could not be obtained. The mica is of ruby colour although rather heavily stained at depth. The pegmatite may yield small-sized mica of workable quality. A similar but thinner pegmatite striking east-west occurs about a quarter of a mile to the north-west of the village. The country rock is porphyroblastic granitic-gneiss.

Dwaragam is 17 miles from Berhampur and 2 miles from the main road. Transport facilities are good. The local labour has no experience of mica-mining.

Mohana (19° 26′ : 84° 16′): West of Ladrimi, close to Mohana and on the southern slope of hill 2553, white and ruby mica occurs in patches in a quartz-rich pegmatite containing only a little felspar. The mica is clear but heavily cracked; down to a depth of 5 feet the sizes are 5 inches to 6 inches across. The pegmatite is intruded into a quartz-garnet-granulitic rock which forms a band in granitic-gneiss.

Sana Raisingi (19° 31′ : 84° 14′): A very small pegmatite in a nullah about a quarter of a mile south of the village yielded very small flakes of mica.

Bada Raisingi (19° 32′ : 84° 15′): About three quarters of a mile to the west of the village, near the same nullah, a larger pegmatite strikes N.N.W.-S.S.E. The 2-foot core of massive quartz is bounded by a felspathic zone with a thin mica-bearing zone, consisting of felspar, quartz and mica, on each wall. The country rock is garnetiferous granitic gneiss. Biotite is abundant with the muscovite. The quality is clear ruby, but the books measure only 2 inches to 3 inches across and are cracked and buckled.

Adaba (19° 31′ : 84° 11′): Just to the south of Jamaguda, near Adaba, a pegmatite striking north-south crops out on the bank of the Harbang nullah. It could be traced for about 20 feet to 25 feet along the strike. It is 4 feet thick and the wide quartz core is finely jointed and crushed. The mica-bearing zone consists of kaolinised felspar and quartz. The mica is a clear ruby averaging one and a half inches to three inches across, but crushed and cracked. The pegmatite is intruded into biotite-garnet-gneiss of granitic type.

Ghudadandi (19° 54′ : 84° 22′): Outside of this village, near the Hathimunda nullah, a small pegmatite vein consists of quartz, microcline and small books of muscovite, without any quartz core. The mica is of ruby variety but the books are thin and only up to two inches square. The country rock is a biotite-gneiss.

Jillundi (19° 54′ : 84° 34′): About half a mile S.S.W. of the village a quartzose pegmatite containing small specks of mica occurs in granite-gneiss country. No workable mica can be expected.

Between the adjacent villages Budiamb (19° 53′ : 84° 33′), Kaindi (19° 54′ : 84° 34′) and Malaspadar (19° 53′ : 84° 34′) there are similar small quartzose pegmatites containing small specks of mica. Only one yielded thin books of heavily stained ruby mica measuring 3 inches to 4 inches across.

Khariguda (19° 49′ : 84° 32′): A deposit of mica was reported from Rogoda Forest, about two miles west of the village. Specks of mica are

found in the country rock, which is a very coarse-grained granitic gneiss but no pegmatite could be found in the locality.

Khetamundali (20° 03′ : 84°44′): Situated within the Jagannath-prosad Forest at a distance of about half a mile west of the village a pegmatite, consisting of a dark coloured felspar and biotite, strikes N.W.-S.E. and is exposed over a length of 70 feet to 80 feet and width of 12 feet. No muscovite occurs. The country rock is a fine-banded garnet-gneiss.

Saba (19° 33′ : 84° 29′): About one mile to the west of this village, on the slope of a hill within the Badagoda Zamindary forest, a small graphic-granite vein in streaky garnetiferous granitic gneiss contains small flakes of muscovite. A similar vein occurs on the hill to the west of Mangalpur (19° 34′ : 84° 29′).

Koraput

(A. K. Dey)

Kyangu (18° 37′ : 82° 08′), *Attalaguda* (18° 37′ : 82° 10′): Mica-bearing pegmatites occur in the crystalline schists and gneisses exposed along the banks of the Kolab river near these two villages in Malakana-giri taluk. The mica is very small in size, rarely more than half an inch in diameter, and the occurrence of large flakes of mica appears unlikely.

Paladaputtu (18° 33′ : 82° 43′): Some buckled amber-coloured mica (books measuring up to 5 inches in diameter) is found scattered in the surface soil overlying a decomposed graphite-bearing pegmatite about a furlong south-east of Paladaputtu, Pottangi taluk. On opening up the deposit, however, the mica disappeared at a depth of about three feet from the surface.

Borriguma (19° 02′ : 82° 33′) : According to Mr. S. C. Chakravarty ruby mica of sizes 5½, 5 and 4 has been obtained from pegmatite veins near Borriguma.

Sambalpur

(B. C. Roy)

In Nawapara subdivision mica pegmatites occur at Babupali (20° 40′ : 82° 44′), Kalimati (20° 36′ : 82° 46′), Mahuabhata (20° 32′ : 82° 44′), Bilianjore (20° 28′ : 82° 42′) and Bhalubahal (20° 26′ : 82° 44′). The mica books are small and are rarely even three inches in diameter. They are also much flawed and stained. No useful deposits occur.

Babupali: A small trial pit was sunk a few years ago in the fields just west of the village on pegmatites in granite-gneiss but were given up owing to the poor character of the mica.

Kalimati: A little mica was seen whilst ploughing over pegmatites recently, but there is no useful deposit here.

Mahuabhata: Some quartz veins and pegmatites, containing traces of poor quality mica, are observed in this vicinity within granite-gneiss.

Bilianjore and *Bhalubahal*: A few mica-bearing pegmatites were exposed in this vicinity, alongside the Khariar road-side, by excavations for *moram*. One vein has an average width of 15 feet but the mica is of no value.

Ruby mica occurs in Bargarh subdivision in pegmatites traversing biotite-gneisses and khondalites at Fraserpur (20° 59′ : 82° 50′), Kenchhodadar (20° 59′ : 82° 51′), Hirapur (20° 58′ : 82° 50′), Maharanimeripur (20° 56′ : 82° 50′), Jharmunda (20° 57′ : 82° 51′), Bhengarajpur (20° 57′ : 82° 54′), Borasamber (20° 56′ : 82° 57′) and other neighbouring localities. Many trial pits and other excavations have been made and scrap mica is scattered about in the old dumps. A mining lease was held by Munshi Karim Hussain for a period of 30 years with effect from the 1st April 1919 over an area of 768·25 acres. Mica in this area is sheared and flawed and could never have been payable to work. Recently, apparently, the reopening of old pits has been contemplated, but such an attempt is unlikely to be successful.

About two furlongs to the west of Fraserpur Mr. S. Krishnaswamy collected books of good ruby mica, generally measuring 1½″ x 1″ and occasionally 2½″ x 1½″, from the bottom of an old excavation made by Kader Hussain of Amthi. The excavation is 67′ long, 65′ 6″ broad and 28′ 6″ deep. The smaller sized books are practically free from cracks but the larger ones are usually badly cracked. One quarry near Kenchhodadar, locally known as Jamuna Khadan, measures 50 feet by 50 feet and is reported to have reached a depth of 40 to 50 feet; the mica veins strike W.N.W.-E.S.E. parallel to the gneissic foliation. Another pit in the same locality, known as Bar Khadan, measures 40 feet by 40 feet and is said to have reached a depth of 100 feet. About three furlongs to the south-east of Kenchhodadar Mr. Krishnaswamy collected samples of good ruby coloured mica from a trial pit that was sunk to a depth of eight feet on a mica bearing pegmatite. Most of the books of mica measured 1½″ x 1″ and the largest was 3″ x 2″. The small sized books happened to be practically free from flaws but the larger books were badly cracked. Near Hirapur one quarry measures 50 feet by 50 feet and its depth is said to be about 45 feet. Mica is also reported to occur around Bartunda (20° 50′ : 82° 45′), Jamset (20° 49′ : 82° 43′) and Temrimal (20° 45′ : 82° 44′) in Bargarh subdivision, but these occurrences have not as yet been visited.

In Sambalpur subdivision, about half a mile north of Burhiakata (21° 18′ : 84° 08′), there is a line of abandoned mica-workings extending for about 400 yards, all apparently on the one vein. The strike is N.E.-S.W. and dip N.W. The pegmatite reaches a maximum of 60 feet in width; it has a typical quartz core 6 feet across, in places of rose colour. The mica is in the felspathic zone on either side, but the books, although up to 12 inches across, are all closely strained. It would be difficult to cut any but the smallest sizes. There seems no possibility that the quality will improve in depth. The deposit is of interest because there is a rare scattering of beryl crystals, ranging in size up to 12 inches long and 4—6 inches diameter. Beryl crystals were found on the dump and it is a pity that these were not collected and sold whilst the mine was working. The deposit is not likely to repay re-opening.

At the villages Bhikampur (21° 31′ : 84° 07′), Barsapali (21° 30′ : 84° 07′) and Jharmunda (21° 31′ : 84° 08′), about 11 miles from Sambalpur, some quartz veins and pegmatites striking parallel with the foliation planes of the gneisses have been prospected. The mica is flawed and sheared and the size rarely exceeds 2 inches in diameter. A pegmatite near Bhimkhoj (21° 18′ : 84° 07′) is reported by Dr. Jhingran to contain mica, but of poor quality.

FUTURE

Most of the prospecting for mica in Orissa has been confined to Sambalpur, Ganjam and Angul. So far it has not been successful, and in view of the normal tendency to over-production elsewhere in India, prospects for the poor quality mica deposits of Orissa are not bright. However, it is at least interesting to know that the Sambalpur and Angul areas, particularly, are mica-bearing and there is always the possibility that pegmatites may be found in which the mica is free from strain and of reasonable size.

CHAPTER XX

MINERAL PIGMENT

GENERAL

Three classes of mineral colours are in commercial use: (1) natural mineral pigments, (2) pigments derived by direct treatment of minerals such as sulphides, (3) chemically manufactured inorganic pigments. The natural mineral pigments include yellow ochre which usually consists of a clay base permeated by hydrated ferric oxide; red oxide which is soft ferric oxide with little or no clay base; umber and sienna which are brown earth colours, containing small amounts of manganese oxide. In addition ground slate and shale are sometimes used as grey pigments.

There is a well-established industry in India for the preparation of colour earths and considerable quantities of oxides and ochres are supplied. At one time India exported large quantities of high quality yellow ochre, but the quality depreciated and the exports ceased.

Occurrences of red and yellow ochres are widely scattered in India, but for the most part they are of inferior quality. Even the poorer ochres find a considerable use locally, for the colour washing of village huts, houses and temples and for various other purposes.

GRADES AND QUALITY

The natural colour pigments may be divided into the red and yellow ochres, the red, brown, purple and black oxides, the siennas and the umbers. The valuation of these requires expert judgment and is dependent upon the richness of colour, staining power, and, in the case of the ochres and oxides, on the iron content.

A simple test of these pigments may be made as follows: A sample is dried and finely powdered, then mixed with oil and spread over a piece of clear glass. The colour as observed through the glass is then compared with prepared samples of standard colours.

Before marketing, most ochres have to be dried, ground, and sieved. In some cases, where mixed with coarse impurities, levigation is necessary. Sometimes the colour may be improved by calcining.

Uses

The ochres of various shades have a reasonably good covering power, are permanent colours and have no effect on other pigments. They are extensively used in the manufacture of paint, oilcloth and linoleum, paper, as a pigment in ceramics, cement, rubber goods, etc.

The oxide pigments are durable, good driers, possess good spreading power and are cheap and inert. They are widely used for painting exposed iron and steel work, such as ships, bridges, railway trucks, and, like the ochres, are used as a pigment in linoleum, wall paper, cement and rubber goods. "Rouge", a finely ground form of pure oxide, is used for polishing metals, glass, etc.

A variety of ferric oxide known as micaceous hematite consists of natural minute thin scales of hematite which, after sifting and mixing with boiled linseed oil, is used for painting exposed iron, steel and wood work.

The brown earth colours, the siennas and umbers, vary in colour from brown to reddish brown and comprise a wide variety of tints. They are largely used in printing and artists' colours, and as a stain and colour filler usually with other colours.

Cuttack

(A. K. Dey)

Ochres have been found at Naraj (20° 28′ : 85° 46′), Talgar (20° 28′: 85° 45′) and Ghasiput (20° 25′ : 85° 37′) in Cuttack, and at Palsabani 21° 00′ : 84° 52′) and Similipal (21° 04′ : 84° 47′) in Angul subdivision.

Naraj (20° 28′ : 85° 46′): At this village thin bands of red ochre are associated with the Gondwana sandstones and clays exposed along the bank of the Mahanadi for a distance of about 2½ furlongs upstream from the Inspection Bungalow. These bands are one to 3½ inches thick and are overlain by sandstones and clays which measure up to 30 feet or more in thickness. The individual bands of ochre vary in thickness and quality. Those directly overlying clay are usually better than those occurring in sandstones. The material is gritty, with a natural purplish red colour. When mixed with oil the colour appears lighter than 2nd grade but darker than 3rd grade red ochre.

On the north-eastern slope of Sideshar Hill, about a mile south-west of Naraj, a small deposit of yellow ochre occurs under laterite. Further west, to the north of the Sideshar temple, on the slope of the hill overlooking the Mahanadi river, a small bed of brownish red ochre rests on a 5-foot clay-bed which has become slightly hardened and splintery by the intrusion of a basaltic rock. Its natural colour is orange. When mixed with oil, the colour appears darker than third grade.

Talgar (20° 28′ : 85° 45′): Thin beds of brownish red ochre are found associated with grey shales exposed on the bank of the Mahanadi north-west of Talgar about 13-14 miles from Cuttack by river. The beds dip 7° towards the south and are seen for a distance of about one furlong. When mixed with oil the colour appears darker than 1st grade.

The following is the sequence from the top:—

	Feet	Inches.
Soil	6	0
Shale	5	11
Brownish red ochre . .	0	2½
Shale	3	0
Brownish red ochre mixed with yellow	0	2½
Shale	3	6
Brownish red ochre	0	3
Shale	3	0
Ochre: poor .	0	2
Shale .	1	0
Brownish red ochre .	0	2½
Shale	2	6
Brownish red ochre	0	2

Ghasiput (20° 25′ : 85° 37′): Thin bands of fine yellow ochre are found here and there in the Gondwana sandstone quarries at this village, in the Dompara Estate. The deposits are usually small and the ochre can only be used locally as colour-wash. Its natural colour is buff yellow : and when mixed with oil the colour is between 2nd and 3rd grade.

Palsabani (21° 00′ : 84° 52′): Red clay associated with Gondwana sandstones and shales in the Balikudia jungle, about 2 miles north-west of Palsabani, has been explored in a small way by three or four pits. The deposit is relatively large and occurs as a bed within 4 or 5 feet of the surface. The material is slightly gritty but has a good covering power. In colour it compares favourably with that of standard good quality Indian red ochre available in the market. It is locally used for dyeing cloths.

Similipal (21° 04′ : 84° 47′): Some of the red clays found associated with the Mahadeva grits and sandstones on the hills south of this village are of good colour and covering power, comparable with the standard good quality Indian red ochre available in the market. These are being prospected.

Pebbles of hematite weathered out from the Mahadeva grits and found lying in the surface detritus on the slopes of hills south of Similipal, and lenses of soft hematite which occur here and there with the sand stones and shales of the Damuda series, are likely to yield material suitable for colouring purposes. The pebbles of hematite derived from the Mahadevas are rather hard and their Fe_2O_3 content is about 48 per cent.

Rankia (21° 02′ : 85° 52′): Boulders are rounded pieces of red ochre were noted by Mr. G. P. Rath at the foot of a quartzite hill north of

the village. The material is probably derived from laterite-hematite and hematite-quartzite. It is siliceous and slightly plastic.

Mr. Rath also came across red, pink and yellow ochres occurring in association with the banded hematite-quartzites near Champajhar (21° 04′ : 85° 56′), Patwali (21° 06′ : 85° 58′) and about 1¼ miles north-east of Santrapur (21° 01′ : 85° 54′).

Ganjam

(G. C. Chaterji)

Red earths formed by the weathering of the garnet-gneisses (khondalites) have been widely used in Ganjam for colour-washing houses and for dyeing cloth. Lateritic fine detritus is also sometimes used for the purpose. However, the best deposits of red ochre are associated with the Gondwana rocks in the Khondmals.

Tnasu (20° 29′ : 84° 01′): About a quarter of a mile S.S.E. of this village a soft fine red ochre occurs as a flat bed under about 2 to 3 feet of soil cover. The exposed thickness of the bed is about 3 feet. It has been worked by the local Khonds by means of small pits covering an area of about 150 square yards, but it probably extends over a much larger area under the red soil cover.

Sirkajori (20° 30′ : 84° 02′): This village is about 2 miles north-east of Tnasu and a similar deposit occurs close by as a horizontal bed under a thin capping of loose red soil. The actual thickness of the bed is not known but it is much more extensive than the Tnasu deposit. Small pits have revealed a depth of about 3 feet, and it continues in depth. The upper portion is rather gritty but it becomes much finer below.

These ochres from Tnasu and Sirkajori were tested in the laboratory, but, although washing made them very fine, the colour and covering power do not compare favourably with standard ochres. Better ochres may be found later in this area. Although labour costs only a few annas per day, transportation charges in this hilly forest country would be very high.

Koraput

(A. K. Dey)

Sarayi (18° 19′ : 82° 45′): A large deposit of red ochre occurs on a low laterite hill about half a mile west of Sarayi village, Pottangi taluk. The material, though slightly gritty, possesses a good tint and a high covering power and is comparable with the best Indian red ochre available on the market.

Geruputtu (18° 35′ : 82° 44′): Another large deposit of red ochre occurs on a laterite-capped hill, 3520, north of Geruputtu, Pottangi taluk. The material is of the same quality as that of Sarayi, and is widely used by the villagers as a colour-wash. An excavation measuring 45 feet in length, 40 feet in width and 20 feet in depth, has been cut into the hill side below the laterite cap near the summit of the hill.

Both Sarayi and Geruputtu are at considerable distances from the railway but close to good roads. The former is about 65 miles from Vizianagram and the latter is about 57 miles from Salur.

Immediately west of Araku village (18° 20′ : 82° 51′) in Vizagapatam district, Madras, close to the Orissa border, there is a fairly large deposit of excellent red ochre similar to the above on a laterite hill. Its analysis is quoted below:—

SiO_2	...	2·23
Fe_2O_3	...	34·66
FeO	...	0·96
Al_2O_3	...	39·84
TiO_2	...	0·91
MnO	..	0·06
CaO	..	0·56
MgO	..	0·53
P_2O_5	..	0·07
Water soluble contents	..	0·06
Loss on ignition	..	20·00
Undetermined	..	0·10
Total	...	100·00

Total Fe	25 per cent.
Total P	0·012 per cent.
Total S	0.069 per cent.

Analysts.—R. V. Briggs & Co.

Kandagam (18° 55′ : 82° 38′): Mr. A. M. N. Ghosh noticed red ochre below a capping of laterite and lateritic soil, some 60 feet thick, at the western edge of the flat-topped ridge to the north-west of Kandagam. Two excavations have been made into the hillside and some 200 bags of ochre have been collected by the contractor. The quality is not apparently good enough for export, although it is used locally. Owing to debris and landslips the quarry face was not properly exposed and its extent could not be determined during examination. The thick overburden of loose laterite and lateritic soil would be the main obstacle in quarrying and the alternative is to drive tunnels into the ochre from the hillside. The roof and the sides would need to be carefully timbered, however. The deposit appears to be fairly large.

Boipariguda (18° 45′ : 82° 26′): Mottled cream and yellow clays are reported by Mr. A. M. N. Ghosh on the west bank of a stream about a

mile north-east of this village. The deposit is about 200 yards long and is interrupted here and there by decomposed gneiss. The clay, which is the decomposition product of hornblende-gneiss, is overlain by 3-4 feet of alluvium and carries pockets of yellow ochre, about 15 to 20 feet of which are exposed on the river bank.

Binusuli (19° 02′ : 82° 18′): Yellow shales are exposed for about 40 feet on the right bank of the Jaura *nala* south of the village, commonly known as Bhonsuli (Binusuli). The material is locally used for colour washing.

Moganda (19° 06′ : 83° 21′): Mr. S. C. Chakravarty noticed a fairly large deposit of red ochre below a capping of laterite, about half a mile west of Moganda. Below the laterite there is an excavation in the hill-side measuring 150′ × 63′ × 20′ (deep). The material is slightly gritty but possesses a good tint and a high covering power and compares favourably with the best Indian red ochre available in the market.

Puri

(G. C. Chaterji)

Red-coloured loamy soil is frequently used as colour-wash by the local people. Deposits of ochre are found in several places in the Khurda subdivision, but the known deposits are not of very good quality. These ochres occur either associated with Gondwana clay beds, or as sub-lateritic coloured lithomarge.

In the Jagannathprasad and Bharathpur forests, the upper portions of the clay beds (noted in Chapter XI) just below the soil cover are coloured red or red and yellow, and in fact most of the Bharathpur clay is coloured a dull mottled yellow and red. The ferruginous staining has obviously come from the soil mantle.

Alongside the B. N. Railway, at Gobindprasad (20° 17′ : 85° 51′) within mouza Bamikhal, a seam of ochreous lithomarge occurs below about 40 feet of laterite in flat open country. Its colour is dull reddish sienna, with patches of white. The seam is flat-lying and is reported to extend over an area nearly 1,000 feet square, with a thickness of about 10 feet. It was mined several years ago by means of shafts and galleries. The material was ground, washed, packed at the mine, and railed to Calcutta, but the work has been abandoned as the colour is not up to market requirements.

Though the colours of these ochres do not compare favourably with standard market varieties of red ochre, the Gobindprasad material may possibly be refined later and marketed as an inferior grade ochre.

Sambalpur

(B. C. Roy)

Materials which may find a use as mineral pigments in Sambalpur include lateritised rocks, altered khondalites, carbonaceous phyllites, Cuddapah and Gondwanas red shales.

The lateritised rocks in Nalibassa hill, Laira Zamindary, contain large deposits of red and yellow ochres associated with white lithomarge. These deposits have been noted in Chapter XI.

Siliceous red ochres derived from weathered garnetiferous schistose gneisses around Chaura hill (20° 07′ : 82° 49′), Gandamer (20° 38′ : 82° 44′) and other localities, are used in the neighbouring villages for colour wash. The Chaura hill deposit is small and inaccessible. The Gandamer occurrence consists of kaolin and impure reddish and yellowish ochre along the gneissic foliation planes, in a small *nala* near the village, and is of little value.

Samples of black soft carbonaceous shales have been reported as coming from Chandiangiri *dungri* near Thuntikatarbaga (21° 42′ : 83° 59′). The material might be used as a black pigment, but the locality has not yet been examined.

Beds of red shales are associated with the Cuddapah sandstones and flagstones around Gerujor (20° 31′ : 82° 36′), Khadupani (20° 13′ : 82° 32′), Jobbhata (20° 10′ : 82° 31′) and Pandripani (20° 11′ : 82° 32′). Some of the shales are soft and the material after grinding and washing improves considerably in quality. The locality is, however, rather in accessible, as it is 15 miles from the Khariar-Nawapara road. The village Gerujor has apparently derived its name from the red shaly pebbles which are found in the adjacent *jore* and which are collected for domestic use. These villages are situated around the Khariar plateau in which soft red shales are associated with quartzites. It is likely that a considerable amount of this red shale debris may be found over a large area at the foot of the plateau.

Just south-east of Khadupani (20° 13′ : 82° 32′), in the plain country, there are outcrops of horizontal red shales; in addition about 2 furlongs south-east of Khadupani and around Jobbhata and Pandripani, some red shales are interbedded with flagstones. The value of such red shales as ochres for industrial purposes is, however, doubtful.

In the Gondwanas of the Rampur coalfield thin seams of soft red shales occur near Liakhai (21°51′ : 83° 50′) and Ulap (21° 51′ : 83° 49′). Just north-east of Liakhai, at the foot of a sandstone ridge, thin red shale seams vary in thickness up to six inches, and others are likely to be found in this zone. About a mile north-west of Liakhai, around Ulap, a red clay seam is interbedded with red flagstones. These occurrences are within 2 miles of the railway, but even if their quality were up to market standard mining in these horizontally bedded rocks would be rather expensive.

The nodular ironstone bands in the Rampur coalfield occasionally weather into concentric, scaly, ochreous patches. Such deposits are scattered over a large area around Chuakani (21° 50′ : 83° 53′), Bagmer (21° 50′ : 83° 54′), Chualiberna (21° 49′ : 83° 53′), Samra (21° 49′ : 83° 51′), Jamkhani (21° 48′ : 83° 52′), Rampur Colliery (21° 48′:83° 55′), Jorabaga (21° 47′ : 83° 52′), Darlipali (21° 46′ : 83° 51′) and Talabira (21° 44′ : 83° 58′). The material is usually a soft, even-grained powder, and the colour varies from red to various shades of chocolate. The quality improves on grinding and washing.

Some of the black shales in the western Jorabaga fireclay quarries may be used as a black pigment.

Future

Apart from the two deposits in Koraput and perhaps some of the Angul ochres, the ochres found to date in Orissa do not raise hopes of an extensive mineral pigment industry. So far as the red ochres are concerned, only the Koraput material is equally to the market colour standard, although the quality of many of the deposits is otherwise good. The best deposits are likely to be found in the Gondwanas and associated with the laterites, and suitable colours in these should be always sought.

Now that manganese deposits have been found in Koraput there is the possibility that suitable siennas and umbers may be found. Indeed, by mining a selection of mineral earths from various parts of the province it may be possible to obtain quite a wide variety of tints to be used as colouring media for pottery and other purposes, should industries requiring them arise.

CHAPTER XXI

MINERAL SPRINGS

Scattered throughout India there are many mineral springs, the waters of which are hot and reported to have medicinal properties. Recently a detailed study of these has been commenced by the Geological Survey, and in Bihar some of the springs have been proved to be highly radioactive and to possess medicinal properties equal to the best European spring waters.

Hot springs are known to occur in Orissa, but no record has been made of them. Ball in 1880 mentioned * a copious spring at Atari (20° 12′ : 85° 33′) in Puri district, having a temperature of 138°F, and which discharged H_2S.

About 25 miles from Berhampur (Ganjam) on the road to Lohagudi there is a celebrated spring called Taptapani (19° 29′ : 84° 04′) from which issues a copious and constant flow of hot water (about 115°F), evolving sulphurous vapour. It is at the headwaters of the Taptapani river, in porphyroblastic granitic-gneiss. The spring, situated in picturesque forest hill country, is much frequented by visitors and some healing properties are claimed for the water.

These springs should be recorded in the future and carefully tested to determine their properties. Those which are found to be of medicinal value should be acquired preferably by Government not only for their preservation but also for their development as health spas.

* Ball, V. Jungle life in India, 8°, London, p. 531.

CHAPTER XXII

MINERAL WOOL

General

If mineral matter is fused and then blown by a blast of air or steam, it is drawn out into fine fibres: this material has been given the name *mineral wool*. There are several varieties of this, depending upon the composition of the original melt: glass melts give *glass wool* or *glass silk*, metallurgical slags give *slag wool*, and fused rock or mixture of rock gives *rock wool*.

Mineral wool was made apparently first in Wales and Germany about 1840; later, in 1870, fibre made from glass and slag from iron furnaces was known as *mineral cotton* in the United States. It was not until 1896, however, that a plant was constructed in Indiana, for manufacturing mineral wool. Since then the technique of manufacturing has considerably improved, and, particularly in recent years, there has been a rapid growth of the industry. In 1936, the production of *mineral wool* in America had risen to 500,000 tons, with a sale value of $6,000,000 with 50 plants in operation.

Krishnan* has drawn attention to the possibility of manufacturing this material in India. He has pointed out the need in a tropical country like India for a cheap insulating material which can be used in building construction.

Uses

The value of mineral wool lies in its heat insulating property and this is due to the still air trapped between the fibres. Experiments have demonstrated that fibres with a diameter of 2-10 microns give the best results. Although not as good a heat insulator as asbestos it is amongst the best insulators. It is used for protecting water pipes, furnaces, stoves, boilers, retorts, smokestacks, ice-boxes, refrigerators, etc. It is used also to deaden sound in buildings, as a filter for air and for certain corrosive liquids, and also as a packing against shock.

Mineral wool is put on the market in various forms according to the use for which it is required.

Loose wool is the material as it emerges from the blowing room and is used in that form for insulating buildings.

Granulated wool is made by passing the loose wool through granulators which break it up into short fibres. This is used for packing into walls, roofs, etc., by blowing it in through a hose with compressed air.

Batts are made by compressing the wool with a binder, and cutting into suitable shapes for use in buildings, in such spaces as beneath floors, in walls, roofs, etc. They are sometimes cut into continuous rolls.

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* Krishnan, M. S. Mineral Wool. *Trans. Min. Geol. Met. Inst. India*, 35(4), 801-421, 1940.

Blankets are rectangular shapes in which the wool is sewn between wire-netting, expanded metal, paper, etc., and may or may not be held together by a binder.

Tiles, bricks, boards and blocks are made by binding the wool with such material as asphalt, plaster, cement, etc., and moulding it into the required shape. They are used for such purposes as lining refrigerators and stoves.

Insulating cement is made by mixing the wool with such binder as clay, bentonite or cement, and is used around irregular objects, steam pipes, etc.

Dress fabrics, heat-resisting ropes and fire-proof curtains have been made from the better soda-lime-silica glass wools.

Raw materials

The raw materials used in the manufacture of mineral wool include broken glass and china, sand, gravel, earth, slag, easily fused rock, shale and impure limestone. But the composition of the material used and the temperature and other physical conditions of manufacture should be kept under control in order that the product may be uniform.

There are no natural rocks in Orissa which could be described as readily fusible. There are, however, deposits of impure limestone and dolomite which could be used, with silica, for the manufacture of mineral wool, perhaps in conjunction with a glass industry or with any cement industry that may be developed.

Production

The raw materials are heated in various types of furnaces: cupolas, reverberatory or electrical furnaces. There are several methods of drawing into fibres. The simplest is to pour the melt in a thin stream across a jet of steam or air, which splits the melt into small globules which are then drawn by the blast into threads. Another method is to drop the molten stream onto a disc revolving at high speed, the droplets are thrown off as fine fibres. The melt may also be spun into threads on a rotating wheel or drum. Exceptionally long fibres may be produced by the latter method.

According to Fryling and White, to produce 2,000 lb. of rock wool the following raw materials are required: 3,000 lb. of rock, 1,200 lb. of coke, 3,000 lb. of steam, 4,000 gallons of cooling water. Accordingly, cost of coke is a large item, but the United States Bureau of Mines estimated that with coke at $ 4 to $ 5 per ton the cost of producing rock wool should be less than $ 20 per ton.

The possibilities of production in India might be fully investigated but it will need careful research on the various processes which could be used before any practical success is likely.

CHAPTER XXIII

QUARTZ CRYSTALS

General

In consequence of the piezo-electric properties of certain quartz crystals, thin slices cut along definite directions in the crystals act as oscillators and resonate to alternating currents of particular frequencies, depending upon the thickness of the quartz slices. A number of such thin slices of varying thickness may, therefore, be used to separate currents of different frequencies sent simultaneously over the one transmission line. They find considerable use, accordingly, wherever electrical oscillators are required, as in multiple telephony and telegraphy.

The crystals required must be untwinned and have well-developed crystal faces; they should be at least 4½ inches long, and 2 inches in diameter and be clear in transparency and free from flaws. Suitability can be determined only after expert examination.

Recently, deposits of quartz crystals have been found in Sambalpur, a very small proportion of which may be suitable for electrical purposes.

Ganjam

(G. C. Chaterji)

About half a mile west of village Binchana (19° 49′ : 84° 36′) on the Berhampur-Russelkonda road, a quartz vein contains some half-formed small quartz-crystals, about 1½ inches long, ½ inch in diameter and very much flawed. These crystals are unsuitable for electrical purposes. The vein has been used for road metal and the biotite-gneiss country rock for building purposes.

Sambalpur

(B. C. Roy)

Rock crystals are common in the gneissic tracts of Sambalpur district. They are known as *Bhatparsi pathar* and are sometimes collected and worshipped by the local people. During the recent mineral survey, deposits were found around Pandri (21° 10′ : 84° 06′), Koinsar (21° 15′ : 84° 07′), Bharimura (21° 13′ : 84° 06′), Jugomura (21° 14′ : 84° 08′), Bhoipali (21° 26′ : 84° 04′), and Meghpal (21° 20′ : 84° 15′).

Pandri: About 5 miles south-west of Jugomura and about 2 furlongs from the Sambalpur-Rairakhol border, rock crystals are developed in a *nala* where quartz veins and pegmatites have intruded into well-bedded quartzites, usually along the foliation planes. The quartzites, with associated schists, have been intruded by granite-gneiss which is the main country rock of this area.

Towards the eastern bank of the *nala*, underneath the quartzite, a vein (No. 1), 6—9 inches wide, of parallel-grouped rock crystals, dips between south-east to E.S.E. at 35°. It crops out for about 20 feet

along the strike but appears to become thinner at the ends and is, therefore, unlikely to extend much beyond. It is traceable for about 5 feet in the direction of the dip and presumably continues in that direction.

Just below No. 1 vein occurs another (No. 2), ranging in thickness from 2 to 4 feet, and containing innumerable fine rock crystals arranged in radial and stellate fashion in cavities.

Towards the western bank of the *nala* and practically below the water, another small vein (No. 3) contains beautiful rock crystals ranging from 2 to 4 inches in length, all arranged in parallel similar to No. 1.

Two quartz veins west of the *nala* contain no well-formed crystals.

The pegmatites near here are very coarse and the felspar crystals are up to several feet across. .Fine rock crystals are occasionally found in geodes in these pegmatites.

Crystals occurring in Nos. 1 and 3 veins range up to 9 inches in length and up to 2½ inches across. Many of the crystals are untwinned and they are transparent or translucent. Traces of green chloritic inclusions are present but ferruginous impurities and gas bubbles are usually absent. The crystals in No. 2 vein are too small to be of value for electrical purposes. Over 100 rock crystals were dislodged from Nos. 1 to 2 veins, varying from a few inches to 9 inches in length, but many were damaged in doing so. However, it is probable that, after testing, a few of these will be suitable for cutting for piezo-electric purposes. Several maunds remain in the vein, which should be extracted with care.

Koinsar: About three furlongs north of the village a vertical quartz vein, about 18 inches in width and striking E.N.E.-W.S.W., crops out for about ten feet along the strike and contains a network of semi-transparent to transparent rock crystals varying up to about five inches in length. Other quartz veins are to be seen in the surrounding gneiss.

About one-third of a mile south-east of Koinsar rock crystals occur in quartz veins on small hillocks. The crystals are arranged in parallel or irregularly in geodes, and are transparent or translucent but occasionally stained by iron oxide. The crystals range up to four inches in length.

Bharimura: About half a mile north-east of the village a few specimens of well-formed but small rock crystals occur in quartz veins forming small *dungris* in flat gneissic country. Most of the material is impure sugary quartz. Other similar occurrences are to be found in this locality, but only a few small rock crystals are likely to be found.

Jugomura: About a mile north-west of this village stray rock crystals are found over a rather plain granitic country. The quartz veins and pegmatites usually follow the gneissic N.E.-S.W. vertical foliation planes.

Bhoipali: Sporadic rock crystals in small druses and cavities in the gneisses occur here, but none of any importance has been located.

Meghpal: Rock crystals are sporadically developed in drusy cavities in quartz veins along the Meghpal ridges. No important deposits were found.

Future

The quartz crystals in Sambalpur occur particularly in a belt of country about 25 miles long and 5 miles broad south of the Basipara-Hatibari-Meghpal hill ranges. Future prospecting should yield a small amount of rock crystals of various sizes and grades, occasional specimens of which may be suitable for electrical purposes. However, it is difficult to see how this could possibly give rise to any permanent mining of a payable nature.

CHAPTER XXIV

REFRACTORY AND CERAMIC MATERIALS

General

The principal material on which a refractory and ceramic industry is based is clay. The deposits of clay known to be available in Orissa are described in Chapter XI. Should these be utilised for a firebrick and pottery industry within the province other materials will be required for this industry, and it is accordingly advisable to summarise the possibilities of obtaining these locally.

Bauxite

One of the uses of bauxite is in the manufacture of aluminous firebricks. Even if not obtainable within Orissa proper, deposits in Kalahandi would be available.

Dolomite

True dolomite consists of calcium and magnesium carbonates in equal molecular proportions, theoretically 45·65 per cent of $MgCO_3$ and 54·35 per cent $CaCO_3$, but usually the proportion of $CaCO_3$ is greater. The term dolomite limestone is commonly used for limestones with between 10 and 40 per cent $MgCO_3$.

These rocks are used, after calcining to the "dead-burned" condition at 1,500°C, for refractory purposes in basic open-hearth furnaces and in Bessemer converters, either as a plaster or in the form of bricks. Dolomite is also used for fettling furnace walls. It may eventually take the place of magnesite as a refractory for steel smelting.

Some of the limestones at Sulai, Padampur and Putka in Sambalpur are dolomitic. Similar limestones even higher in magnesia occur also in Gangpur State, rather closer to Jamshedpur, so that it is doubtful whether the Sambalpur material would be quarried for use in the steel works in Bihar.

FELSPAR

Felspar is used in the manufacture of good quality pottery and porcelain ware. The mineral is available in the pegmatites of the province. Dr. Roy records that large crystals of orthoclase and microcline felspar up to one foot across occur in the pegmatites at Laikera (21° 53′ : 84° 13′), Laira (21° 44′ : 84° 13′) and Gambharpalli (21° 48′ : 84° 16′), whilst at Pandri (21° 10′ : 84° 06′) the crystals are several feet across.

FIRECLAY

Fireclays are, of course, the basis of a refractory industry. As noted in Chapter XI, resources of fair quality fireclays are by no means small in Orissa and any industry that may be commenced will be assured of practically permanent supplies.

GRAPHITE

Graphite crucibles are now manufactured in India, but it is doubtful whether the quality of the available local graphite reaches the standard of that used in imported crucibles. One of the reasons advanced is that most Indian graphite contains much mica, lowering its fusibility.

The graphite deposits known to occur in Orissa have been described in Chapter XV. In view of the fact that the manufacture of graphite crucibles has already commenced elsewhere in India, it may not be easy to establish such an industry in Orissa using graphite from the province and from the adjacent Eastern States.

SILICA

Silica, in the form of quartz, is extensively used in the refractory industry for the manufacture of silica bricks. For this purpose a rather pure crushed quartzite is used. Quartzites of sufficient purity are widely scattered in Ganjam, Koraput and Sambalpur.

Silica, in the form of sand, is also used for moulding sands. River sands such as those along the Mahanadi could be used.

If quartz of a special purity is required for any purpose in ceramics these could be obtained from the quartz veins in Sambalpur, around Jharsaguda, Rengali, Gumlai, Naikpara and Parmanpur. Other quartz veins occur in Ganjam and Koraput.

In Koraput, Dr. Dey found a band of white quartzite near the estate bungalow at Dalapur (18° 46′ : 82° 19′), and another on a low hill north of milestone $\frac{7}{7}$ about three furlongs north-east of the above locality. The material is practically pure quartzite containing very little impurities. It is easily crushed.

STEATITE

For many centuries talcose stone materials have been used in various parts of India for the manufacture of dishes and cooking pots, and for carving into ornaments and images.

Besides its ancient use as a potstone, the purer forms of soapstone and talc-schist have more modern uses for refractory purposes, and as a polishing medium and filler. A certain amount is also mixed with clay in some pottery.

As a refractory, talc is commonly used in the manufacture of gas burners as well as in small furnaces and stoves. Within recent years steatite bricks have come into increasing use where resistance to corrosion, especially by high alkaline slags, is necessary, for example in the Wagner alkali smelting furnaces at the recovery end of paper mills. In the powder form the material is widely used as a polishing agent for glass and leather and in rice milling, also in the manufacture of soap, as a foundry facing, as a filler in paint, paper and textiles as a lubricant, and in the manufacture of certain wall plasters. Slabs are cut into panels for table tops, switch boards and for tanks.

Deposits of steatite occur here and there in the Jeypur and Malakanagiri taluks. Some large deposits were found by T. L. Walker on the Malakanagiri road some five miles beyond Kollaru or Kolar (18° 42′ : 82° 24′). The material is massive and occurs as bands in the quartzites and well-foliated biotite-gneisses. Three deposits of steatite have recently been examined in the district: (*a*) half a mile west of Antigam (18° 52′ : 82° 32′), (*b*) one mile W.N.W. of Majjiguda ((18° 47′ : 82° 26′), and (*c*) a road cutting one mile north of Minoroballi (18° 45′ : 82° 22′). All of these deposits of talc occur as inclusions in the granite-gneiss. The Antigam deposit is now abandoned and the pits filled with debris, and the deposit at Minoroballi is of very poor quality. The Majjiguda deposit is schistose and chloritic, but is used for making milestones.

At Mahamuhan (21° 21′ : 86° 40′) in Balasore, there is still a small industry in the mining and working of potstone. The material appears to be a talc-tremolite rock and is found abundantly on the hill north of the village. The deposits are not worked so actively as formerly. Some old workings on the hill illustrate the extent of mining in the past.

Mr. G. P. Rath has recorded small deposits of steatite at the following localities in the Sukinda Estate in the Cuttack district:—(1) 6 miles south-east of Sukinda Khas (20° 58′ : 85° 55′), (2) about a furlong south-east of Kharipadia (20° 56′ : 85° 56′), locally called Kharidi, (3) about a mile north-east of Ambasar (20° 55′ : 85° 56′), (4) about a mile south-west of Biswanathpur (20° 57′ : 85° 55′), (5) two furlongs west of Tungaisuni (21° 03′ : 85° 53′), (6) along the *nalas* and on the small hills which form parts of the large quartzite range between Champajhar (21° 04′ : 85° 56′) and Kansa (21° 04′ : 85° 52′) and to the north of Tungaisuni (21° 03′ : 85° 53′) near the Keonjhar border, the deposits are small and scattered but the total reserves appear to be considerable, (7) in the bed of a *nala* about half a mile east of Nuagaon (20° 58′ : 86° 01′), (8) near Garhpur (20° 58′ : 86° 02′), and Kachuringa (20° 57′ : 86° 03′), both close to the B. N. Railway. The deposits have been reported as promising and those near Kachuringa were worked in the past, and (9) about a mile north-east of Kansa (21° 04′ : 85° 52′).

Sillimanite

Sillimanite is an alumina-silicate which is now widely used abroad in high-grade ceramic ware, such as in spark plug porcelains and in

insulators, and is also used for refractory purposes, particularly in furnaces where temperature fluctuations and other conditions are severe, as in glass furnaces.

In India deposits of sillimanite are known in Assam and Rewah State, but they are rather inaccessible. Extensive deposits of an equivalent mineral, kyanite, occur in Kharsawan State. Sillimanite-quartz-schists are known to occur in Orissa and they may be expected to occur more particularly with the khondalites; it is with similar rocks that the massive sillimanite deposits of Assam occur. It is, therefore, not at all improbable that, during the future mapping of the Archean rocks of Orissa, deposits of massive sillimanite may be found.

CHAPTER XXV

SAND

General

A very large amount of sand is used in a wide variety of industries. No statistics of sand production are available in India, but the quantities used in building, road-making, stowing in coal-mines, and in the glass industry only must run into many thousands of tons each year.

Sands occur as detrital deposits, usually along stream beds. As a rule sand grains range in size from 0·02 inch to 0·2 inch, above the latter size they grade into grits and gravels. Sometimes soft friable sandstones which can be readily crushed are used as sands.

Most river sands are rather impure. The main constituent consists, of course, of quartz grains, but in addition grains of felspar, mica, argillaceous material, and iron oxides are commonly present, with frequently very small amounts of other minerals.

As a rule sands require a certain amount of treatment before they may be used. For many purposes sands must be sized by sieving through a series of screens. Washing may also be necessary to remove clay material, mica and organic matter. For certain purposes, such as in the glass industry, the sands must be of a particularly high degree of purity.

Uses and properties

For building purposes, in mortars and concrete, a clear sand is preferred, and usually a sharp sand, *i.e.*, one with angular rather than rounded grains. For use on roads a clear sand is not essential, and close screening is not necessary.

The properties of glass sands have been described in Chapter XIII. Purity and reasonably close sizing are here essential, and for this reason sands which can be used for this purpose are rare, and they are commonly obtained by crushing friable pure sandstones.

A large amount of sand is used in India by foundries, as moulding sands in which the metal is cast. Sands for this purpose must have

special properties, and are used mixed with other materials. The moulding sand, as used, must have cohesiveness in order to retain the shape of the pattern, and naturally it must be sufficiently refractory not to be fused by the molten metal. Gases are given off by the molten metal, so that the moulding sand must be sufficiently permeable to allow the escape of these. As a rule large castings are cast in moulds made from a coarser sand than is used for small castings. The moulding sand mixture varies also for the type of metal to be cast. For iron a very high quality sand is not essential, a good cohesiveness is the main thing. For steel castings a good quality fine sand is used with special binders. For casting aluminium, lead, copper, brass or bronze, particularly if great detail is essential, very fine sand must be used with special binders. All foundries have their own moulding mixtures which are invariably the result of considerable experiment.

Other metallurgical uses of sands are for lining and patching certain furnaces, cupolas, ladles and vessels that are used for holding molten metal. For all of these purposes a high-grade material is necessary.

For the manufacture of ferro-silicon a very pure quartz sand of even grain size is essential.

For the manufacture of refractory silica bricks and for use in ceramic ware a very pure silica sand is essential, and for this reason detrital sands are rarely used, crushed sandstone or quartzite being the main source.

Sand is used for filtering water. For this purpose it should be free from clay and organic matter, and the grains should be evenly sized. Some sands contain a high proportion of heavy minerals like magnetite, ilmenite, rutile, etc.; in certain filters, on agitation, these heavy grains settle to the bottom and soon become difficult to clean in the reversing current.

For abrasive purposes, such as in cutting and dressing stone and in sandblasting, the quartz grains may be either rounded or angular and, of course, not high in impurities. For making sandpaper a crushed sand is used. In the manufacture of silicon carbide a pure quartz sand is necessary.

Finely ground sand is used for many purposes, such as a filler in paint, in special plasters, as grit for poultry, in tooth pastes, cosmetics and dental powder, for frosting glass and in soaps and polishes. For these purposes a pure material is required, and, instead of detrital sands, quartz from quartz veins or from mining operations is used.

Distribution

The river sands of Orissa are not sufficiently pure for glass-making, except for the manufacture of inferior qualities such as bottle glass. Even for this purpose there are few places along the river beds where the quality of the sand would remain consistent after successive monsoons. Any friable white Archean, Cuddapah or Gondwana sandstones which may be found in the future should be tested for use as glass sands.

For foundry purposes local sands could be used. Sands for such other purposes as for building and filters are obtainable almost anywhere in the province. There is, perhaps, scope for a rather detailed examination of the sands of Orissa to determine their composition, suitability for certain purposes and even the eventual establishment of such industries as the manufacture of abrasives.

CHAPTER XXVI

MINERAL OCCURRENCES OF LITTLE OR NO ECONOMIC VALUE

Alum

(B. C. Roy)

Alum has been found in an exposure of shale, about 10 feet wide, associated with folded quartzites about 50 feet above the bed of the Indra river, on its southern bank, nearly half a mile west of Jharnamal (20° 25′ : 82° 37′). It is merely of mineralogical interest and has no economic value.

Beryl

Associated with the mica pegmatite at Burhiakata (21° 18′ : 84° 08′) in Sambalpur district and Nanguliabera (20° 48′ : 83° 11′) and Baideswar (20° 21′ : 85° 23′) in Cuttack, crystals of beryl (beryllium-alumina-silicate) were found. The Burhiakata occurrence is unusual, as the amount of beryl, although small, is larger than is found in any of the Bihar mica mines. The crystals were unfortunately thrown unrecognised on the dump heap at the time of mining, otherwise they could easily have been collected and sold. It would not pay to reopen this deposit merely to work the little beryl that does occur. None of the other mica-bearing pegmatites of Orissa have been found to contain appreciable amounts of beryl.

Gemstones

Diamonds: The earliest account of the production of diamonds from the beds of the Mahanadi and Ib, Mand and other tributaries is by Mott* who visited Sambalpur in 1766. Other early accounts are by Breton (1827)†, Kittoe (1839)‡, Ousley (1839)§, Voysey (1844)$ and Ball (1877)**. According to Ball, who examined the best known

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* Asiatic Annual Register, London, (1799).

† Breton, P.: Account of the diamond workings and diamonds of Sumbhalpore, *Edin. Journ. Sci.*, VII, pages 134-140, (1827).

‡ Kittoe, M.: Account of a journey from Calcutta *via* Cuttack and Puri to Sambalpur, and from thence to Mednipur through the forests of Orissa, *Journ. A.S.B.*, VIII, pages 367-383, (1839).

§ Ousley, J. R.: Note on the process of washing for gold dust and diamonds at Heera Khoond, *Journ. A.S.B.*, VIII, pages 367-383, (1839).

$ Voysey, H. W.: Extracts from the late Dr. Voysey's Journals, when attached to the Trigonometrical Survey in Southern and Central India, *Journ. A.S.B.*, XIII, pages 853-862, (1844).

** Ball, V.: On the diamonds, gold and lead ores of the Sambalpur district *Rec. Geol. Surv., India*, X, pt. 4, pages 186-192, (1877).

area, Hirakund (21° 32′ : 83° 56′), the source of the diamonds is the neighbouring " Vindhyans " of the Baripahar hills. So far, no diamond-bearing horizons have been found in the rocks of these hills. More information may emerge when they are geologically mapped in detail.

Hirakund is a small island, about 3 miles long and half a mile broad, between two channels of the Mahanadi about 5 miles north-west of Sambalpur town. Coarse porphyritic granite-gneiss crops out with intercalations of quartz-schists and quartz-mica-schists, which usually follow the foliation planes of the gneiss. The schists form depression in the rocky gneiss and this may have favoured the retention of the diamondiferous gravels carried down by the Mahanadi. Before the British took possession of the district from the late Raja Narain Singh, diamond washing was extensively practised at Hirakund. Temporary *bunds* across the northern channel at the upstream end of the island deflected the stream into the southern channel. The gravels in the bed of the river were washed in the stagnant pools. According to Breton, 20 stones were reported to have been obtained between 1804 and 1818, but no authentic reports are available concerning subsequent finds.

Garnet: Brown transparent garnets occur in vein-like bodies in the granite-gneiss around Mudapala (20° 07′ : 82° 45′) and other localities, but it is doubtful whether any semi-precious varieties could be found.

Rock crystal: The occurrences of rock crystals in Sambalpur have been described in Chapter XXIII.

Rose quartz: Occurrences of quartz with pale rose tint are rare. Some have been observed near Rangiatikra (21° 51′ : 84° 17′), Ghichamura (21° 46′ : 84° 06′) and Burhiakata (21° 18′ : 84° 08′).

Ilmenite

During 1923-24 the beach sands along the coast of Orissa were examined by Crookshank and Lahiri. Deposits of ilmenite sands were found at several places for distances of several miles. In Cuttack district between the Mayapura, Mohana and Mahanadi rivers the average width of these beds of ilmenite sands was about 40 to 55 feet, and thickness up to one foot. The ilmenite content has never been actually determined.

Mr. Mukti Nath noticed small pieces of ilmenite scattered on the southern slope of a small hill, locally known as Jogi Mundia, near Kumandol (19° 48′ : 85° 16′) in the Banpur tehsil of Khurda subdivision, Puri district. The deposit is, however, not of economic importance.

Lead-silver

(B. C. Roy)

No workable deposits of lead-ore have been found in Orissa. A few occurrences of merely mineralogical interest have been recorded, all from Sambalpur district. As is usual with such lead minerals, on analysis a little silver is found to be associated. None of these occurrences hold out any hope for the future finding of workable deposits in the province.

Junai (21° 32′ : 83° 56′): Ball* recorded an occurrence of a vein of galena in the northern bank of the Mahanadi river near Junai. He described the deposit as a true quartz-galena lode in the granitic gneiss. It was reported to be about 6 feet in length with a width 16 to 19 inches. The samples of galena on assay yielded 12 oz 5 cwt. of silver per ton of lead. Some exploration was undertaken but was abandoned in the absence of any skilled guidance.

When visited in 1940 pieces of galena and traces of malachite with quartz gangue and ferruginous gossan were noticed around the old excavations which are overrun by jungle. One galena sample from the debris was found to contain 3·27 oz. of silver per ton of lead.

Thuntikatarbaga (21° 42′ : 84° 00′): Some lead-ore samples originating from around Thuntikatarbaga were brought for identification by the local people when Dr. Roy was camping nearby during the season 1938-39. On assay, the material yielded 58·74 per cent lead and showed the presence of carbonates of copper and phosphate of lead. On later examination of the occurrence, at the north-western edge of Chandandungri (1,251 ft.) traces of lead-ore with malachite and pyromorphite were seen disseminated in a zone of silicified breccia. Some small excavations were made without any encouraging results.

Talpatia (21° 57′ : 84° 01′): Ball* reported the presence of rolled pebbles of lead ores near Talpatia in the Ib river bed. According to him, the matrix of the lead ores was likely to be present "in a small hill to the north of Talpuchia, which consists of fault rock and gossan". The hill, which evidently marked a zone of silicified fault-breccia, was recently visited but no trace of mineralisation could be seen. The pebbles are recorded to have yielded 87·28 per cent lead; they have been transported presumably from the Sargipali (22° 03′ : 83° 55′) lead-ore area in Gangpur State.

Padampur (21° 45′ : 83° 34′): Ball reported the presence of galena in the bed of the Mahanadi at Padampur, occurring as irregular strings and nests in limestone. Recently search was made for the occurrence without success. Just south of Padampur, a fault zone between limestone and granite-gneiss shows no sign of mineralisation.

MONAZITE

Monazite, a phosphate of rare earth minerals, is the source of cerium and thorium used mainly for the manufacture of gas mantles.

During 1923-24 Crookshank and Lahiri investigated the coastal sands of Ganjam and Cuttack respectively. Between Mayapura, Mohana and the Mahanadi river, and near Dowdeswell and False Point naturally concentrated deposits of black sand have an average width of about 55 feet and a thickness less than one foot. The monazite content does not normally appear to exceed 2·5 per cent, although a few local concentrates have yielded between 8 and 12 per cent. The richest concentrates from the sand dunes contain only one to two per cent of the mineral. The deposits of Dowdeswell and False Point are

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* Ball, V.: On the diamonds, gold and lead ores of the Sambalpur district, *Rec. Geol. Surv. India*, X, pt. 4, pages 191-192, (1877).

patchy in character and extend for a distance of about eight miles with an average width of about 40 feet and a thickness of six inches or so. They do not seem to contain more than one per cent of monazite.

Along the Ganjam coast, between Chilka lake and Chicacole river, a large number of small deposits of black sand consist mainly of ilmenite, monazite, zircon and garnet. The monazite content of these deposits is generally low, the best yielding only about five per cent of the mineral. Although not rich enough for the exploration of monazite, the ilmenite content may permit some of them to be worked, perhaps, some time in the future.

According to Mr. S. C. Chakravarty, the thoria content of the monazite sands of the Ganjam coast lying between the Bahuda and the Rushikulya rivers, does not exceed 1.55 per cent.

Vinayak Rao recorded monazite in the sands of the Kolab river, Koraput district, in 1927. It is presumed that the mineral has been derived from the charnockites which are the country rocks of the area.

CHAPTER XXVII

ROAD METAL

Road metals are readily available in most parts of the province, away from the coastal alluvium. In general, it may be said that the fine-grained rocks are more suitable than the coarser types, as the latter disintegrate rapidly as compared with the finer rocks. In every case, only fresh rocks should be used, and altered or decomposed material rejected. Any rock which is highly cleaved should be avoided as a road metal, as it breaks up rapidly along the cleavage.

Fine-grained basic charnockites and dolerites provide the best material for roads which are to carry heavy traffic. Fine-grained dense quartzites are also excellent.

Granite, granite-gneiss, and acid charnockite may be used for medium to heavy traffic, provided they are fine-grained. If any coarse minerals are present, particularly felspar, they disintegrate easily along the cleavage faces.

Sandstone should not be used as road metal, unless fine, compact and silicified. Friable sandstones should never be used. Quartz, from quartz veins, may be used for roads carrying medium traffic.

Limestone may be used for medium traffic, but it wears rapidly following the rains, and gives rise to a very dusty road surface.

Laterite should be used only for light traffic on *katcha* roads.

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CUTTACK DISTRICT

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GANJAM DISTRICT

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	Tnasu	20° 29′ : 84° 01′	114
Mineral spring—	Taptapani	19° 29′ : 84° 24′	118
Quartz crystals—	Binchana	19° 49′ : 84° 36′	121

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KORAPUT DISTRICT

Minerals present—China clay, fireclay, pottery clay, quartzite, gold, graphite, iron-ore, limestone, manganese, mica, ochres, steatite.

Mineral		Place		Co-ordinates		Page
Bauxite—						
		Girligumma	...	19° 07′ : 82° 55′	...	33
		Mandaru	..	19° 56′ : 83° 33′	...	33
		Padwa	...	18° 22′ : 82° 41′	..	33
Clays—						
China clay	...	Ambodala	...	19° 49′ : 83° 28′	...	52
		Ladipanga	...	19° 40′ : 83° 30′	...	53
		Madhupur	...	19° 53′ : 83° 28′	..	53
		Musoriguda	...	18° 52′ : 82° 41′	...	52
		Nuagam	...	19° 06′ : 82° 30′	..	52
		Oduguda	..	18° 48′ : 82° 45′	...	50
		Pittakonda	..	18° 11′ : 81° 56′	...	53
		Pukkili	.	18° 30′ : 82° 54′	...	52
		Singarajukunta	.	18° 17′ : 81° 48′	..	53
Fireclay	...	Boipariguda	...	18° 45′ : 82° 26′		50
		Deodra	..	19° 18′ : 82° 27′	...	50
		Jodiguda	..	18° 20′ : 82° 46′	.	52
Pottery clay	...	Bodosal	..	18° 52′ : 82° 35′	..	49
		Demsaguda	.	18° 51′ : 82° 35′	...	49
Glass-making material—						
Quartz vein	.	Motu	..	17° 50′ : 81° 24′	...	69
Quartzite	...	Dalapur	...	18° 46′ : 82° 19′	...	69, 124
Gold—						
		Battiguda	...	18° 39′ : 82° 24′	...	71
		Dingiyaput	...	18° 36′ : 81° 15′	..	71
		Doraguda	...	18° 34′ : 82° 17′	...	70
		Godiali	...	18° 34′ : 82° 14′	..	71
		Govindpalle	...	18° 35′ : 82° 17′	...	71
		Kollaru	...	18° 42′ : 82° 24′	...	71
		Kyangu	...	18° 37′ : 82° 08′	..	71
		Mandukali	..	18° 35′ : 82° 13′	..	71
		Salimi	...	18° 36′ : 82° 04′	..	71
Graphite—						
		Ambodala	...	19° 49′ : 83° 28′	...	75
		Arugali	..	19° 26′ : 83° 38′	...	75
		Badegaon	...	19° 54′ : 83° 30′	...	75
		Chuchkona	...	19° 09′ : 83° 15′	...	75
		Deppaguda	...	19° 43′ : 83° 28′	...	75
		Dhanimaska	...	19° 51′ : 83° 33′	...	75
		Dullerugam	...	19° 46′ : 83° 33′	...	75
		Jagadalapur	...	19° 46′ : 83° 33′	...	75
		Karriguda	...	19° 35′ : 83° 42′	...	75
		Kumbhiabhatta	...	19° 45′ : 83° 55′	...	75
		Majikelam	...	19° 28′ : 83° 27′	...	74
		Purutula	...	19° 47′ : 83° 34′	...	75
		Sindiputtu	...	18° 31′ : 82° 31′	...	75

KORAPUT DISTRICT—*contd.*

Mineral	Place	Co-ordinates	Page
Iron-ore—			
	Amba Devi ...	... ..	82
	Beluapani ...	... ...	82
	Chitra ..	19° 04′ : 82° 29′ ...	83
	Daipara . .	18° 21′ : 82° 14′ ...	83
	Doraguda ...	18° 47′ : 82° 21′ ...	83
	Gaudavalasa . .	18° 28′ : 83° 00′ .	83
	Garbarai hill ...	19° 29′ : 82° 35′ . .	82
	Gunnayyapada ...	18° 35′ : 82° 32′ ...	83
	Hirapur hill near Umarkot ...	... ...	81
	Iralagondi ...	18° 17′ : 81° 42′ ...	83
	Kalimala ...	18° 04′ : 81° 45′ .	83
	Kumari ..	19° 38′ : 82° 14′ ...	81
	Madhugulimi ...	19° 19′ : 82° 49′ ...	82
	Metteruguda ...	18° 15′ : 81° 35′ . .	83
	Punji Pakna ...	... ...	82
	Santemra ...	19° 38′ : 82° 32′ . .	82
	Singanguda ..	18° 13′ : 81° 32′ ...	83
	Siraguda . .	18° 31′ : 82° 08′ ...	83
	Tilondi ...	... ...	82
	Umarkot ...	19° 40′ : 82° 15′ ...	81
Limestone—			
	Guptesvara ...	18° 49′ : 82° 10′ ...	38, 87
	Kondajodi ...	18° 57′ : 82° 15′ ...	38, 88
	Kottametta ...	18° 20′ : 81° 42′ ...	38, 87
	Nandivada ...	18° 19′ : 81° 40′ ...	87
	Sirivada ...	18° 50′ : 82° 10′ ...	87

KORAPUT DISTRICT—*concld.*

Mineral	Place		Co-ordinates		Page
Manganese—					
	Ambadala	...	19° 50′ : 83° 28′	..	100
	Bariguda	...	19° 30′ : 83° 27′	...	100
	Barijolla	...	19° 11′ : 83° 23′	...	100
	Damanaguda	...	19° 05′ : 83° 11′	..	99
	Devajolla	...	19° 02′ : 83° 12′	...	100
	Devudala	...	19° 14′ : 83° 24′	..	100
	Khalkona	...	19° 03′ : 83° 09′	...	97
	Korapur	...	18° 39′ : 82° 43′	...	95
	Kotandoravalasa		18° 29′ : 82° 54′	...	100
	Kutingi	...	19° 05′ : 83° 10′	...	95
	Kuttili	..	19° 07′ : 83° 12′	...	99
	Loharakuttilli	...	19° 06′ : 83° 11′	...	99
	Mandhara	...	19° 03′ : 83° 12′	...	100
	Muniguda	...	19° 38′ : 83° 29′	...	100
	Pathar Dongar	...	19° 47′ : 83° 28′	...	100
	Pullabadi		19° 09′ : 83° 13′	.	99
	Rayagada	..	19° 10′ : 83° 25′	..	95, 99
	Santemra	...	19° 38′ : 82° 32′	...	100
	Tittiveru	...	18° 22′ : 81° 46′	...	100
Mica—					
	Attalaguda	..	18° 37′ : 82° 10′	...	109
	Borriguma	..	19° 02′ : 82° 33′	...	109
	Kyangu	...	18° 37′ : 82° 08′	...	109
	Paladaputtu	...	18° 33′ : 82° 43′	...	109
Mineral pigments—	Araku	...	18° 20′ : 82° 51′	...	115
Red ochre ...	Geruputtu	...	18° 35′ : 82° 44′	..	114
	Kandagam	...	18° 55′ : 82° 38′	...	115
	Moganda	..	19° 06′ : 83° 21′	...	116
	Sarayi	...	18° 19′ : 82° 45′	...	114
Yellow ochre ...	Binusuli	...	19° 02′ : 82° 18′	...	116
	Boipariguda	...	18° 45′ : 82° 26′	...	115
Steatite—					
	Antigam	...	18° 52′ : 82° 32′	...	125
	Kolar	...	18° 42′ : 82° 24′	...	125
	Majjiguda	...	18° 47′ : 82° 26′	...	125
	Minoroballi	...	18° 45′ : 82° 22′	...	125

PURI DISTRICT

Minerals present—Building materials, fireclay, iron-ore, ochre, mineral water.

Mineral		Place		Co-ordinates		Page
Building materials—						
Sandstone	...	Andharwa Protected Forest, near Bharathpur	..	20° 18′ : 85° 47′	....	39
		Bhubaneswar	...	...	...	39
		Khandgiri	.	20° 16′ : 85° 47′	...	39
		Nayapali	..	20° 17′ : 85° 49′	.	39
Lime	...	Jatia hill	..	19° 41′ : 85° 12′	..	40
Clays—						
Fireclay	...	Barthali Mundia		20° 20′ : 85° 51′	...	53
		Bharathpur	.	20° 18′ : 85° 47′	...	54
		Jagannathprasad		20° 20′ : 85° 46′	.	54
		Kantabar	...	20° 19′ : 85° 43′	..	53
Lithomarge	...	Patharkatta	..	19° 48′ : 85° 17′	..	55
Coal—						
		Athgarh basin	..	..	..	65
Iron-ore—						
		Jatia hill	...	19° 41′ : 85° 12′	...	83
Mineral pigment—						
Ochre	...	Gobindprosad	...	20° 17′ : 85° 51′	...	116
Mineral spring—						
		Atari	...	20° 12′ : 85° 33′	...	118

SAMBALPUR DISTRICT

Minerals present.—Bauxite, building materials, china clay, fireclay, lithomarge, coal, gold, graphite, iron-ore, mica, mineral pigments, quartz crystal, dolomite, felspar, silica, alum, beryl, diamond, garnet, lead-silver, rose-quartz.

Mineral	Place	Co-ordinates	Page
Bauxite—			
	Barepat Dongar	20° 20′ : 82° 27′ ...	33-34
	Kandamal Hills	20° 16′ : 82° 28′ ..	33-34
	Sainipara Hill ...	20° 18′ : 82° 27′ ..	33-34
Building materials—			
Building stones	Chhiplima ..	21° 21′ : 83° 54′ ..	41
	Kardola ...	21° 10′ : 84° 54′ ..	41
	Kulia ...	21° 30′ : 84° 04′ ...	41
	Kutrajori ...	21° 28′ : 84° 05′ ..	41
Clay—			
China clay ...	Banjipali ...	21° 21′ : 83° 46′ ...	60
	Baresinghari ..	21° 25′ : 83° 56′ ..	60
	Chuhukitikra ...	21° 39′ : 84° 09′ .	59
	Dangachhancha ...	20° 54′ : 83° 02′ ...	61
	Dessar .	21° 37′ : 83° 52′ ...	59
	Ghichamura ...	21° 46′ : 84° 06′ .	59
	Katapali ..	21° 24′ : 83° 37′ ...	60
	Paharsigira ...	21° 28′ : 83° 46′ ...	59
	Piplipali . .	21° 22′ : 83° 36′ ...	60
	Sagunpali . .	21° 35′ : 84° 01′ ...	59
Fireclay ...	Ainlapali .	21° 47′ : 83° 54′ ..	57
	Balput ...	21° 46′ : 83° 54′ ...	57
	Baripahar ...	21° 46′ : 83° 47′ ..	57
	Bundia ...	21° 47′ : 83° 53′ ...	56
	Chualiberna ...	21° 49′ : 83° 53′ ...	57
	Darlipali ...	21° 46′ : 83° 51′ ...	56
	Jorabaga ...	21° 47′ : 83° 52′ ...	55
	Katabaga ...	21° 47′ : 83° 56′ ...	57
	Khola ...	21° 39′ : 83° 39′ ...	58
	Kirarama ...	21° 46′ : 83° 53′ ...	57
	Kudopali ...	21° 47′ : 83° 54′ ...	57
	Lukopali ...	20° 46′ : 82° 33′ ...	58
	Rampur ...	21° 46′ : 83° 55′ ...	56
	Talabira ...	21° 44′ : 83° 58′ ...	57
Lithomarge ...	Akhradand ...	21° 39′ : 84° 12′ ...	61
Coal—			
	Rampur ...	21° 46′ : 83° 55′ ...	63

SAMBALPUR DISTRICT—*contd.*

Mineral	Place	Co-ordinates	Page
Gold—			
	Dantamura ..	21° 43′ : 83° 56′ ..	72
	Hirakund .	21° 32′ : 83° 56′ ..	72
	Sonamohan .	21° 46′ : 84° 13′ .	72
	Tahud ...	21° 36′ : 84° 02′ ..	72
Graphite—			
	Babupali	20° 39′ : 82° 44′ .	76
	Baghmunda	20° 31′ : 82° 45′	76
	Bardhapali .	20° 53′ : 82° 59′ .	78
	Bilianjore	20° 28′ : 82° 42′ ...	77
	Buren .	20° 53′ : 83° 01′ .	78
	Dahigaon .	20° 56′ : 83° 06′	78
	Dangachhancha .	20° 54′ : 83° 02′ ..	78
	Gandamer .	20° 38 : 82° 45′	76
	Kumna .	20° 30′ : 82° 42′ ..	76
	Padampur .	21° 00′ : 83° 04′ .	78
	Sargipali ...	20° 55′ : 83° 05′ .	77
	Silatpali . .	20° 52′ : 83° 00′ .	78
	Tentulkhunti ...	20° 57′ : 83° 07′ ...	78
Iron-ore—			
	Akhradand ...	21° 39′ : 84° 12′ ...	84
	Bindrabahal .	20° 21′ : 82° 34′ ...	84
	Chikalchua ...	20° 14′ : 82° 33′ ...	84
	Khirapali . .	21° 09′ : 82° 57′ ...	84
	Kholigaon .	20° 34′ : 82° 34′ .	84
	Kotgaon ...	20° 15′ : 82° 34′ .	84
	Lohakhand ..	21° 41′ : 84° 09′ ...	84
	Mahuabhata ..	20° 47′ : 82° 33′ ...	84
	Majhgaon ...	20° 35′ : 82° 34′ .	84
	Mundher ...	21° 21′ : 84° 05′ ...	85
	Podapali ...	20° 20′ : 82° 46′ ..	84

SAMBALPUR DISTRICT—*contd.*

Mineral	Place		Co-ordinates		Page
Limestone—					
	Badmal	...	21° 40′ : 83° 33′	...	88
	Banjipali	...	21° 38′ : 83° 30′	...	88
	Behera	..	21° 39′ : 83° 32′	...	88
	Dungri	...	21° 42′ : 83° 34′	...	88
	Kusunda	...	21° 37′ : 83° 30′	...	88
	Lakhanpur	...	21° 38′ : 83° 37′	...	88
	Nawapara	..	21° 09′ : 82° 57′	...	92
	Padampur	...	21° 45′ : 83° 34′	...	88, 89
	Putka	...	21° 10′ : 82° 58′	..	88, 91
	Sauntmul	...	21° 41′ : 83° 33′	...	88
	Silhatpani	...	20° 36′ : 82° 35′	...	88
	Sulai	...	21° 58′ : 84° 06′	...	88
Mica—					
	Babupali	..	20° 20′ : 82° 46′	...	109
	Barsapali	...	21° 30′ : 84° 07′	...	110
	Bartunda	...	20° 50′ : 82° 45′	...	110
	Bhalubahal	.	20° 26′ : 82° 44′	...	109
	Bhengarajpur	...	20° 57′ : 82° 54′	...	110
	Bhikampur	...	21° 31′ : 84° 07′	...	110
	Bhimkhoj	...	21° 18′ : 84° 07′	...	110
	Bilianjore	...	20° 28′ : 82° 42′	...	109
	Borasamber	...	20° 56′ : 82° 57′	..	110
	Burhiakata	...	21° 18′ : 84° 08′	...	110
	Fraserpur	..	20° 59′ : 82° 50′	..	110
	Hirapur	...	20° 58′ : 82° 50′	...	110
	Jamset	...	20° 49′ : 82° 43′	...	110
	Jharmunda	...	20° 57′ : 82° 51′	...	110
	Jharmunda	...	21° 31′ : 84° 08′	...	110
	Kalimati	...	20° 36′ : 82° 46′	...	109
	Kenchhodadar	...	20° 59′ : 82° 51′	...	110
	Maharanimeripur		20° 57′ : 82° 51′	....	110
	Mahuabhata	...	20° 32′ : 82° 44′	...	109
	Temrimal	...	20° 45′ : 82° 44′	...	110

SAMBALPUR DISTRICT—*contd.*

Mineral pigments—

Bagmer	.	21° 50′ : 83° 54′	...	117
Chaura hill	.	20° 07′ : 82° 49′	...	117
Chuakani		21° 50′ : 83° 53′	...	117
Chauliberna		21° 49′ : 83° 53′	...	117
Darlipali		21° 46′ : 83° 51′		117
Gandamer	.	20° 38′ : 82° 44′	...	117
Gerujor		20° 31′ : 82° 36′	...	117
Jamkhani		21° 48′ : 83° 52′	..	117
Jobbhata	.	20° 10′ : 82° 31′	..	117
Jorabaga		21° 47′ : 83° 52′	...	117
Khadupani		20° 13′ : 82° 32′	..	117
Laikhai		21° 52′ : 83° 50′	..	117
Nalibassa hill (Laira Zam.)		.. ...	...	117
Pandripani	..	20° 11′ : 82° 32′	...	117
Rampur Colliery		21° 48′ : 83° 35′	..	117
Samra		21° 49′ : 83° 51′	..	117
Talabira	..	21° 44′ : 83° 58′	...	117
Thuntikatarbaga		21° 42′ : 83° 59′	...	117
Ulap		21° 51′ : 83° 49′	..	117

Quartz crystals—

Bharimura	..	21° 13′ : 84° 05′	...	121, 122
Bhoipali		21° 26′ : 84° 04′	..	122
Jugomura	...	21° 14′ : 84° 08′	...	121, 122
Koinsar	...	21° 15′ : 84° 07′	...	121, 122
Meghpal	...	21° 20′ : 84° 15′	...	121, 123
Pandri	...	21° 10′ : 84° 06′	...	121

SAMBALPUR DISTRICT—*concld.*

Refractory and ceramic materials—				
Dolomite ...	Padampur ...	21° 45′ : 83° 34′	...	
	Putka ..	21° 10′ : 82° 58′	...	
	Sulai .	21° 58′ : 84° 06′	..	
Felspar ..	Gambharpalli ...	21° 44′ : 84° 16′	..	
	Laikera ..	21° 53′ : 84° 13′	..	
	Laira ..	21° 44′ : 84° 13′	..	
	Pandri ..	21° 10′ : 84° 06′	.	
Silica ...	Gumlai ...	... ..	.	
	Jharsugura ..	. ...	.	
	Naikpara .	... ...	..	
	Parmanpur ...	.. ..	..	
	Rengali ...	... .	...	
Mineral occurrences of little or no economic value—				
Alum ...	Jharnamal .	20° 25′ : 82° 37′		
Beryl .	Burhiakata	21° 18′ : 84° 08′	...	
Diamond .	Hirakund ..	21° 32′ : 83° 56′	..	
Garnet ...	Mudapala ..	20° 07′ : 82° 45′	...	
Ilmenite .	Kumandol ...	19° 48′ : 85° 16′	.	
Lead-silver .	Chandandungri ...	... ...	..	
	Junai ...	21° 32′ : 83° 56′	...	
	Padampur ...	21° 45′ : 83° 34′	...	
	Sargipali (Gangpur State) ...	22° 03′ : 83° 55′	...	
	Talpatia ...	21° 57′ : 84° 01′	...	
	Thuntikatarbaga	21° 42′ : 84° 00′	...	
Monazite ...	Ganjam-coast ...	.. ...	...	
Rose quartz ...	Burhiakata ...	21° 18′ : 84° 08′	...	
	Ghichamura ...	21° 46′ : 84° 06′	...	
	Rangiatikra ...	21° 51′ : 84° 17′	...	

Sree Saraswaty Press Ltd., 32, Upper Circular Road.